HEALTH OF INDIANA FIREFIGHTERS

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DEDICATION

This dissertation is dedicated to my parents, Norman G. Silvey and Mary M. Silvey; husband, David A. Muegge; four-leggers; brothers; nephews; and GREAT nephews Gabriel J. Silvey and Carter T. Silvey.

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Background: Firefighters are exposed to carcinogens, toxic agents, and other risks for cancer and cardiovascular disease. Research shows that aero-digestive and genitourinary cancers are in excess among firefighters compared to the general population. Studies examining excess cardiovascular mortality are inconsistent. Limited data exist on chronic disease mortality, risk factor profiles, and barriers to a healthy lifestyle among firefighters at the local level.

Purpose: This project examines the relationship between firefighting and chronic disease mortality, determines trajectories of cardiovascular risk factors in a cohort of new firefighters, and studies the relationship between barriers to weight management and firefighter health characteristics.

Methods: This study used death certificate data from the Indiana State Department of Health and clinical data from a large occupational medical practice serving firefighters. Regression techniques were used to examine excess mortality among firefighters compared to non-firefighters, evaluate changes in cardiovascular disease risk factors among new firefighters over time, and explore correlates of risk factors and barriers to weight management among overweight and obese firefighters.

Results: The odds of death due to malignant cancers were significantly higher among firefighters than non-firefighters (OR, 1.19; 95% CI, 1.08-1.30). Body mass index, total cholesterol, LDL cholesterol, and triglyceride levels increased significantly ($p<0.001$) while HDL cholesterol levels decreased ($p<0.001$) from baseline during the first 10 years of the firefighter's career. Overweight firefighters who were "ready to begin a weight management program” were more likely to identify ‘‘lack of knowledge about weight management,’’ ‘‘lack of access to exercise opportunities,’’ and ‘‘eating helps me cope with stress’’ as barriers, and report a greater number of barriers to weight management. Older firefighters were less likely to identify or report one or more barriers to weight management.

Conclusion: These studies suggest the importance of early-career and targeted cardiometabolic health and cancer prevention strategies to reduce chronic disease morbidity and mortality among firefighters.

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LIST OF ABBREVIATIONS

APSM	Ascension Public Safety Medical
BMI	Body Mass Index
CDC	Centers for Disease Control and Prevention
CHD	Coronary Heart Disease
CI	Confidence Interval
CLR	Conditional Logistic Regression
CPAT	Candidate Physical Ability Test
CVD	Cardiovascular Disease
FEMA	Federal Emergency Management Agency
HDL	High Density Lipoprotein
HRA	Health Risk Appraisal
HWE	Healthy Worker Effect
ICD	International Classification of Diseases
ISDH	Indiana State Department of Health
LDL	Low Density Lipoprotein
ln	natural logarithm
MOR	Mortality Odds Ratio
NFPA	National Fire Protection Association
OR	Odds Ratio
PMR	Proportionate Mortality Ratio
SCD	Sudden Cardiac Death
TG	Triglycerides
US	United States
WPE	Work Performance Evaluation

CHAPTER 1 INTRODUCTION

Firefighters are exposed to carcinogens, toxic agents, and other factors increasing their risk for cancer and cardiovascular disease [1-3]. Due to the lack of firefighter-level exposure data, studies examining death certificates have been used for decades to assess disease-specific fatalities attributable to firefighting. This research showed firefighters may be at increased risk for death due to multiple myeloma [4], non-Hodgkin's lymphoma [1, 4], prostate cancer [1, 4], testicular cancer [1, 4], skin cancer [4], malignant melanoma [4], brain cancer [4], rectal cancer [4], buccal cavity and pharynx cancers [4], stomach cancer [4], colon cancer [4], and leukemia [4] compared to the general population. Groundbreaking work conducted by Daniels et al. [5, 6] found excess cancer mortality among firefighters for malignancies of the biliary tract, esophagus, gall bladder, intestine, kidney, liver, lung, oral cavity (buccal and pharynx), and rectum, and leukemia and mesothelioma.

Findings from mortality studies on cardiovascular disease were inconsistent. Studies conducted by Mastromatteo and others [7-12] found more circulatory-renal and cardiovascular disease deaths among firefighters compared to the general population, while others reported fewer deaths among firefighters [13-20] or no relationship between firefighting as an occupation and cardiovascular disease, at all [5, 21-29].

In the United States (US), cardiovascular disease (CVD) is the most common cause of line-of-duty death among firefighters. Surveillance shows that sudden cardiac death accounted for the largest proportion (49%) of on-duty firefighter fatalities in

2019 and 44% over the past decade [30]. Furthermore, estimates suggest as many as 25 non-fatal line-of-duty cardiovascular events occurring among firefighters for each on-duty fatality [31, 32].

Even with limitations in surveillance and mortality research, such as reliance on surveys and variation in methods, findings from these studies have provided evidence of a potential increased risk between firefighting and cardiovascular disease and cancer and justification for additional research exploring exposures related to chronic disease mortality. Cardiovascular disease among firefighters is understood today primarily due to research that has been conducted during the past three decades. Current knowledge shows that sudden cardiac events occur among firefighters on the fire ground when the "*threshold for cardiovascular strain"* [33] is exceeded by the independent or combined stress of firefighting activities [3, 34-39] and in firefighters with underlying coronary heart disease [3, 34, 35, 37, 38, 40-42] and structural heart abnormalities [37, 38, 40-43] and among those with an increased burden of cardiovascular risk factors. The major modifiable traditional cardiovascular risk factors include inadequate levels of physical activity, poor nutrition, hypertension, unhealthy cholesterol levels, excess consumption of alcohol and smoking, which may be intensified by inadequate amount of sleep related to shift work, risk factor clustering, and stress [3, 33-35, 38, 40, 41, 44].

Obesity is a well-established risk factor for CVD [45-47]. Obesity also increases the burden of existing CVD risk factors by clustering the negative effects of blood pressure, lipids, glucose metabolism, sleep related breathing problems, and cardiac hypertrophy [45, 48, 49]. Among firefighters, being overweight and obese are related to less than optimal health status and cardiovascular risk profiles [34, 35, 40, 44, 49-51], including lower levels of cardiorespiratory fitness [3, 44], metabolic syndrome [3, 38] coronary heart disease (CHD) [52], on-duty CHD events and deaths [40], injury [53], disability [54], and CVD-related retirements [40].

Obesity-associated metabolic abnormalities such as metabolic syndrome and hypertension are independently or jointly associated with an increased risk for coronary heart disease or structural heart abnormalities, adding to cardiovascular risk through additional physiological pathways [34]. Despite the health risks, 75% to 80% of career and volunteer firefighters have been identified as overweight (body mass index [BMI] greater than or equal to 25 kg/m^2). Among firefighters who are overweight, up to 40% are obese (BMI greater than or equal to 30 kg/m^2) [3, 44, 49-51, 55], including fire service recruits [56, 57].

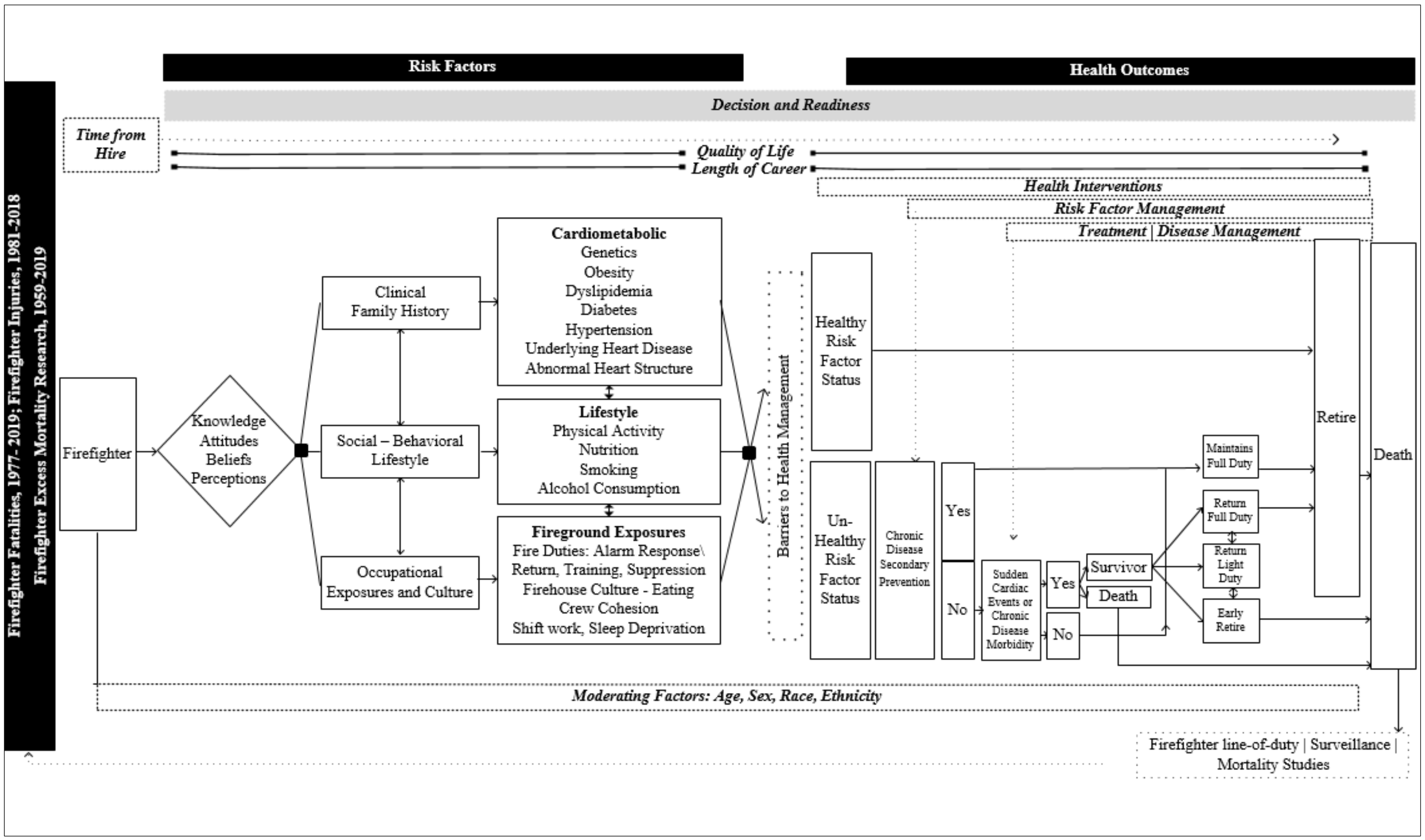
Nevertheless, the understanding of health risks associated with obesity among firefighters has improved over the past twenty years, but little is known about the barriers that firefighters face to manage their weight or overall health status. Evidence suggests that diets high in fast food, sugary drinks [58], carbohydrates and saturated fats [58-60], along with the firehouse culture of second helpings and large portion sizes [61, 62] likely contribute to obesity. The cost of healthy food, time needed for meal preparation, and low levels of support for healthy eating both at home and in the firehouse have been reported by firefighters as obstacles to behavior change [62, 63]. Misconceptions about healthy food choices and difficulty knowing which information about nutrition was accurate [63] have also been cited as barriers to good nutrition.

Given the lack of requirements among US fire departments for routine medical surveillance of firefighters, limited data and research exist on firefighters' cardiovascular risk factor profiles. Furthermore, studies examining risk profiles of new firefighters and changes in risk over time are even more limited. In Indiana, Ascension Public Safety Medical (APSM), an occupational medical practice providing health and wellness services, has more than 20 years of clinical, fitness, and social-behavioral data on firefighter health and wellness, including new firefighters' measures. This data warehouse is one of the largest and most comprehensive data sets of firefighter health and fitness measures in the United States. Examination of these data independently or combined with other data sets will help investigators and health planners fill gaps in firefighter research and target health programs. Since a large portion of this data set is serial data from firefighter annual physical examinations, these data can be used to examine changes in health measures among new firefighters and well-defined cohorts over time.

Therefore, the purpose of this research was to leverage available data to build an understanding of firefighter health status by first examining the leading cause of death among Indiana firefighters and determining if those causes of death were in excess of those of the general population. Then, secondly, measuring levels of cardiovascular risk factors among a group of newly hired firefighters and characterizing the trajectory patterns of changes in these risk factors in the first 10 years of the their career, and finally examining barriers to weight management among overweight and obese firefighters and exploring how these barriers might be related to age, sex, readiness for change, level of physical activity, fruit and vegetable consumption, body weight status, cigarette smoking, and binge drinking.

The conceptual model illustrating the approach to this research, *"*Health of Indiana Firefighters,*"* is shown in Figure 1. The overarching structure of this model is based on existing research, clinical knowledge, career patterns, and determinants of firefighter health, including health behaviors influenced by fire service culture and environment. The model establishes that firefighter line-of-duty fatality and injury surveillance data, along with findings from excess mortality research, serve as population level tools for identifying cardiovascular disease as a leading cause of firefighter death and measuring change in health outcomes associated with health promotion program planning. The model also shows that firefighter knowledge, attitudes, beliefs, and perceptions facilitate behaviors affecting clinical, family history, social-behavioral, occupational and cultural risk factors associated with the development and progression of cardiovascular disease. However, moderating the relationship between knowledge, attitudes, beliefs, and perceptions toward behaviors and healthy risk factor status are barriers to health management such as access to healthy food [58-60], firehouse culture [61, 62], and lack of support for healthy eating [62, 63]. Such obstacles prevent firefighters with good intentions from achieving a healthy risk profile and mitigating risk for CVD, cancer and other chronic diseases. Limited information is available on obstacles firefighters face to adopt and maintain behaviors conducive to health. Studies examining characteristics and patterns of change in risk factors over a firefighter's career are also limited. When combined, risk factor profiles, health and disease status affect quality of life and the length of the firefighter's career. Therefore, the conceptual model is intended to serve as a guide for firefighter chronic disease research. This multilevel model highlights a complex inter-relationship among exposures, barriers, and behaviors influencing careers and health outcomes that are not well-understood for firefighters. Research to better understand these complexities will enable the development of targeted health interventions and increase the likelihood of attaining positive health outcomes among firefighters.

Figure 1. Conceptual Framework for Health of Indiana Firefighters



CHAPTER 2 EXCESS MORTALITY AMONG INDIANA FIREFIGHTERS, 1985-2013

Introduction

Firefighters are exposed to known carcinogens and toxic agents in combustion products that are not completely mitigated by protective equipment and safety procedures [2, 64], increasing their risk for cardiovascular disease and cancer [3, 65]. Due to the lack of individual level exposure data, mortality studies have been conducted over the past several decades to better understand disease-specific deaths attributable to firefighting. The findings of this research, however, are inconsistent. Studies conducted by Mastromatteo [7] and others found more circulatory-renal [7, 8] and cardiovascular disease deaths [9-12] among firefighters compared to the general population while others reported fewer deaths [13-20]. In 2005, Ma et al. [66] found female firefighters had excess atherosclerotic heart disease mortality compared to Florida women, but a deficit among male firefighters. More studies found no relationship at all [5, 21-29].

In regard to cancer, there is evidence suggesting firefighters may be at increased risk for death due to multiple myeloma [4], non-Hodgkin's lymphoma [4, 64], prostate cancer [4, 64], testicular cancer [4, 64], skin [4] malignant melanoma [4], brain [4], rectum [4], buccal cavity and pharynx [4], stomach [4], colon [4], and leukemia [4].

Landmark work conducted by Daniels et al. [5] in 2013 found excess cancer mortality among all firefighters for the esophagus, intestine, rectum, lung, kidney, oral cavity (buccal and pharynx), liver, gall bladder, and biliary tract. This work also found for the first time that deaths due to mesothelioma were in excess for firefighters compared to the general population. Bladder and prostate cancer deaths were in excess among younger firefighters. A follow-up study conducted by Daniels et al. [6] showed increasing mortality risks for lung cancer and leukemia among firefighters with cumulative exposure.

In 2015, Ide [67] compared mortality in Scottish firefighters 1984-2005 to age-matched controls. The mean rate of death among firefighters was lower than the matched comparison group; however, the kidney cancer death rate was higher among firefighters. Recent studies of firefighters [18-20] showed no significant excess cancer mortality, except Petersen et al. [21] who reported stomach cancer mortality was higher among firefighters.

Findings from previous heart disease and cancer mortality studies among firefighters have been somewhat inconsistent. While there was some agreement in the findings, studies varied in methods and geography. Timeframe of studies has varied, as well, with concurrent changes in both firefighting techniques and advances in medical science for the detection and control of disease. Thus, continued research is needed to better understand the relationship between firefighting and increased risk for chronic disease mortality. The purpose of this study was to examine patterns of chronic disease deaths among Indiana firefighters from 1985 to 2013 compared to non-firefighters. This study is unique in that it is one of the first studies to match an exposed firefighter population to an independent comparison group of non-firefighters from a general population to control for possible confounding due to age, sex, race, ethnicity, and year of death by design and employ conditional logistic regression procedures to control for the matched factors in the analysis. This study design incorporates robust methodology that can be used in place of proportionate mortality ratio studies and stratified analyses when denominator data for the target occupational population are not available.

Methods

A matched case-comparison design using death certificate data provided by the Indiana State Department of Health (ISDH) was used for this study. Trained ISDH staff used the industry and occupation codes to identify adult decedents as firefighters or non-firefighters for each year of the study, 1985-2013. Key variables in each record included year of death, age at time of death, sex, race, ethnicity, industry code, occupation code, and underlying cause of death. A total of 2,848 firefighter death records were identified for 1985-2013. Thirty records (n=30) were excluded due to unknown race (n=2) or ethnicity (n=24), being under 18 years of age (n=2), or not exactly matching to four comparison cases (n=2). Thus, 2,818 firefighter and 11,272 matched comparison death records were included in the final analysis. To address the study sample size limitation stated by previous studies, each firefighter death record was matched to four non-firefighter death records to improve statistical efficiency and power as well as to control potential confounding variables.

Four non-firefighter controls per firefighter case were selected based on a power calculation that showed 81% power to detect the investigators' chosen minimum important (3%) difference between proportions of the two independent groups (using 47% vs 50% which is more demanding or conservative than proportions near 0 or 1.0) using a chi-square test, when the number of cases was 2,818 and the controls were four times that number (11,272) [68]. The study protocol was reviewed by the Indiana

University Institutional Review Board on May 11, 2015 and determined to be non-human subject research.

IBM SPSS Statistics Version 24.0 (SPSS) [69] was used to match each firefighter record to four randomly selected non-firefighter records with the exact same age at time of death, sex, race, ethnicity and year of death using a non-replacement process. Windows PowerShell [70] was used to join and collate matched records to produce the final dataset for analysis. Underlying cause of death codes were mapped to natural language according to the National Institute for Occupational Safety and Health-119 Codes by Category, 1960-2007 for the 9th (1985-1998) and 10th revision (1999-2013) of the International Classification of Diseases (ICD) [71]. Mapping of ICD codes to cause of death was checked by two reviewers. Each reviewer checked 500 randomly selected rows of data. Ninety-eight percent (98%) of the data were coded correctly.

Statistical analysis

Cross-tabulation analyses were used to assess and compare the frequencies and distribution of demographic characteristics and causes of death. Student's t-tests were used to compare continuous variables; chi-square tests were used for categorical variables. Exact conditional logistic regression (CLR) models were fit using the SAS LOGISTIC procedure specifying the “exact” and “strata” statements to account for matching in each cause of death model. Exact conditional odds ratios, Wald 95% confidence intervals, and P-values from these analyses were used for interpretation and reporting (SAS 9.4) [72]. Cause of death was the dependent variable and occupation (firefighter or non-firefighter) was the exposure in each model. Z-tests were used to test the difference between proportions for heart disease and cancer in 5-year categories.

P-values less than 0.05 were considered statistically significant.

Results

The mean number of firefighter deaths by year was 97, ranging from 68 deaths in 1985 to 155 in 2013. The mean age at time of death was 71.3 years. Nearly three-quarters of subjects (73.2%) were 65 years and older. About a quarter (23.4%) were 80-89, thirty percent (30.3%) were 70-79, and 23.4% were 60-69 years of age. Ten percent (10.4%) were 50-59. Almost all subjects were white (96.0%), non-Hispanic (99.9%) males (98.8%). There were 33 female firefighters in the dataset.

Leading causes of death

The leading cause of death for all firefighters for 1985-2013 was malignant neoplasms (30.4%) (Table 1). Malignant neoplasms of the respiratory system, digestive organs and peritoneum, and other and unspecified sites (37.1%; 22.9%, 14.5%, respectively of cancers) accounted for three-quarters (74.5%) of all malignant cancer deaths. Heart disease was the second leading cause of death (29.2%). Three quarters of these were deaths due to ischemic heart disease (75.1%). An examination of firefighter deaths in 5-year increments showed that the proportions of heart disease deaths were higher in 1985-1989 (38%) and 1990-1994 (34%) than cancer deaths for the same time periods (32%, 28%, respectively). While the proportion of cancer and heart disease deaths trended down over time, the burden of cancer significantly surpassed heart disease in 1995-1999 (36% vs 29%, p=0.03), 2000-2004 (34% vs 27%, p=0.02) and 2010-2013 (28% vs 23%, p=0.04).

Heart disease was the leading cause of death in the non-firefighter comparison group (29.6%) followed by malignant neoplasms (27.1%). Deaths due to diseases of the respiratory, other circulatory, and digestive system ranked as the third, fourth, and fifth leading causes of death in both study groups. Three percent of firefighters (2.9%) and non-firefighters (3.0%) died due to diabetes mellitus and another 2% in both groups died due to violence. Most of the violent deaths in both groups were intentional self-harm (89.8% firefighters, 76.3% non-firefighters).

While the number of female firefighters in the database was small (n=33), available data showed that most often they died of heart disease (n=9, 27.3%), specifically ischemic heart disease (n=5, 55.5%), and cancer (n=9, 27.3%). Most female firefighter cancer deaths were due to malignant neoplasms of the respiratory (n=5, 55.5%) and digestive system (n=3, 33.3%).

Excess mortality

The odds of death due to all malignant cancers combined was significantly higher for firefighters than non-firefighters (OR, 1.19; 95% CI, 1.08-1.30) (Table 2). This study found no evidence of increased odds of death due to neoplasms of the respiratory system and most other cancers, as well as no differences in cardiovascular mortality experience between firefighters and non-firefighters. Firefighters were found to more commonly die of malignancies of the buccal cavity and pharynx (OR, 2.15; 95% CI, 1.19-3.79), other parts of the buccal cavity (OR, 4.00; 95% CI, 1.07-14.96), pharynx (OR, 2.26; 95% CI, 1.05-4.65), pancreas (OR, 1.45; 95% CI, 1.01-2.06), and kidney (OR, 1.84; 95% CI, 1.17-2.83). Deaths due to malignancies of other and unspecified sites (OR, 1.27; 95% CI, 1.02-1.56) were also elevated among firefighters, due specifically to connective tissues (OR, 2.50; 95% CI, 1.01-5.86) and brain and other parts of the nervous system (OR, 1.98; 95% CI, 1.23-3.12). There was no difference in the odds of heart disease deaths, including ischemic heart disease, between the two groups. However, the odds of other circulatory system deaths (OR, 0.80; 95% CI, 0.68-0.94), specifically cerebrovascular disease (OR, 0.82; 95% CI, 0.67-0.996) were significantly lower among firefighters. Accidental poisoning deaths (OR, 0.43; 95% CI, 0.16-0.95) were also lower for the firefighters. All other causes of death did not significantly differ between the two groups.

Discussion

This study found Indiana firefighters experienced an estimated 20% increase in the odds of dying due to malignant cancer compared to non-firefighters. Firefighter deaths due to cancers of the oral cavity, kidney, pancreas, and brain were higher than that of the matched comparison group Findings from this study support previous work that firefighting may be associated with cancers of the kidney [5, 29] and brain [4]. Unlike previous work, this study found an increased odds of death due to malignant neoplasms of connective tissue among firefighters. The cerebrovascular disease deaths among firefighters were significantly lower than for non-firefighters suggesting a healthy worker effect [73]. While there was not a significant relationship, the odds of death due to heart disease, specifically ischemic heart disease, were also lower among firefighters.

Over the past 20 years, a great deal of knowledge has been gained about cardiovascular disease and cancer risk in the fire service. Translation of this information to educational resources for use in department wellness and training programs are among the tools available to help firefighters maintain their health. In Indiana, the largest fire department in the state has implemented an occupational health program for two decades. Firefighters working in this department have been required to pass a pre-employment physical agility test for the past 15 years, a mandatory physical fitness test annually for approximately 20 years, and an annual performance evaluation for the past 5 years, suggesting they may have access to better medical screening and follow-up treatment compared to the general population. Other Indiana fire departments have adopted varying levels of health and fitness evaluations during the past decade, further supporting the influence of the healthy worker effect on the firefighters' risk of heart disease death, while not significant, was lower than that of their matched peers. Firefighters participating in wellness programs may also place a higher value on their personal health status, adhering to age and sex dependent screenings and referrals leading to prevention and early detection of heart disease.

Firefighters staying healthy throughout their careers may be more likely to stay on the job, leading to increased exposure to carcinogens during fire ground activities. While data were not available for employment duration, the average age of death among firefighters was 71 years, suggesting long firefighting careers for most. Given that kidney and brain cancer mortality sub-type findings were consistent with large meta-analyses, reviews and other investigations, it seems less likely these findings were due to chance alone. Connective tissue cancer deaths, a rare cancer type in the general population, [74] were also found to be higher among firefighters. Limited data are available for risk factors for soft tissue cancers. However, the National Cancer Institute reports family history, past exposure to radiation, and exposure to chemicals such as vinyl chloride and arsenic as possible risk factors for this cancer [75].

This investigation applied the general principles of a matched case-control study using the odds ratio as the measure of effect to examine excess mortality. Matching was used to create a comparison group with characteristics similar to the firefighter population to compare cause of death. Matching summary statistics showed that the general population's demographic characteristics were not similar to the firefighter population prior to matching. For this study, exact matching improved the comparability of the two groups. This is one of the first studies to use this design with death certificate data. Other investigators used the case-control approach, but relied on cancer registry data [76]. While the overall strategy of computing an odds ratio to compare the mortality experience of an occupational group to the general population is not new [76, 77], matching firefighter to non-firefighter death records was novel for this type of study. This method controls for possible confounders and utilizes conditional odds ratio as the measure of effect, a preferred technique among epidemiologists for analyzing data when the outcome is a dichotomous variable.

Proportionate mortality ratios (PMR), unconditional mortality odds ratios (MOR), and chi-square tests were also computed to conduct sensitivity analyses. While not reported, the only difference found among these methods was in the comparison of deaths due to assault and homicide. Using PMR and chi-square as the effect measures, firefighters had significantly lower odds for death due to assault and homicide, whereas this difference was not significant when comparing these causes of death with the unconditional MOR or conditional OR. All four measures were in the same direction; however, the magnitude of the unconditional MOR and conditional OR did not reach statistical significance. While all of the measures were consistent, the CLR methods accounting for matching in the design and analysis were expected to be most reliable [78]. Furthermore, these methods can be applied when denominator data are not available for inclusion in the study. Such an approach eliminates bias of interdependence in PMR and controls for potential confounding in design and analysis, thus reducing the need for stratification and difficult interpretation with many covariates. These methods can be applied across all geographic regions, large and small, bringing tools for consistency into occupational mortality study design methods enhancing investigators' ability to compare study outcomes. Matching, which was a challenging and difficult task in the past, can now be accomplished using of all Indiana firefighter deaths over a 29-year time period, making the results generalizable to an entire state, versus a single large fire department.

Consistent with previous mortality research, a major limitation of this study was lack of occupational and lifestyle exposure information. A review by Soteriades et al. [3] reported inadequate levels of physical activity, poor dietary habits, smoking, obesity, hypertension, dyslipidemia, and diabetes mellitus among firefighters dying due to coronary heart disease events in the line-of-duty. These authors also indicated that occupational exposures such as smoke exposure, noise, shift work, and stress might contribute to increased risk for cardiovascular disease. Exposures related to second jobs or careers were also not assessed. Given the "extensive overlap" in risk for CVD and cancer, these same exposures may also increase a firefighters risk for cancer [79]. The lack of availability of risk factor information prevents for the adjustment of these covariates in modeling and a more direct examination of the impact of the occupation of firefighting on mortality. A second limitation of this study is the potential for misclassification of cause of death and occupation. While misclassification of cause of death is likely non-differential for firefighters and the general population, misclassification of death could influence outcomes when the observed numbers of deaths for any category were small. While reported, interpretation and use of these results should be conducted with caution. Occupational misclassification may have also occurred as some non-exposed matches may have been volunteer firefighters, moving the effect toward the null. However, after being in firehouses and talking with firefighters, we believe that firefighters strongly identify with the culture and this type of misidentification does not often happen. In the few instances this may have happened, the effect on the odds ratio would probably be toward the null. In a study of death certificate data quality, Saywell et al. [80] examined the quality of the "industry" and "occupation" codes that showed 92.7% and 84.6% accuracy, respectively. Another factor that may have introduced misclassification bias was characterizing firefighters and non-firefighters into a single exposure group Firefighters change rank, job assignments, and move to different firehouses throughout their careers, possibly influencing exposure over time. Non-firefighter decedents represent all categories of other work groups with varying degrees of occupational health risks and environments. Errors in cause of death coding on the death certificate are also possible.

Having numerator-only data for a mortality study is also a limitation of this work. While it would be ideal to compare specific cause of death between populations through standardization, the use of the matched design and analysis removes the interdependence of proportions, adjusts the measure of effect by matching the variables to better estimate the association between the occupational exposures and outcomes. Mortality odds ratios (MOR) are common measures of effect for occupational health that epidemiologists use to determine if a specific mortality (an outcome) has a relationship to occupation (as an exposure) in a matched case-control study [77]. Thus, matching firefighter and non-firefighter death records and examining odds ratios and confidence intervals is an alternative approach to approximate the cause specific mortality ratio between firefighters and non-firefighters when denominator data are not available. Lastly, there was not a sufficient number of female firefighters in the dataset to examine their causes of mortality with confidence.

Although there are limitations to this work, a review of death certificate data helps investigators, health program planners, and policy makers understand the patterns of death due to chronic diseases among firefighters. This study adds to the existing evidence that firefighters may be at increased risk for malignant cancers.

Conclusion

Overall, the odds of specific malignant cancer deaths were found to be statistically greater among Indiana firefighters as compared to a matched population of non-firefighters. Furthermore, the leading cause of firefighter deaths, cancer and heart disease, underscore the need for implementing and expanding cancer and heart disease risk factor reduction programs and policies for firefighters. While factors that impact an individual's cause of death are very complex and often not well defined, known risks exist and can therefore be reduced through supportive polices as well as risk reduction programs. Psychological stress, job-related shift work, and sleep deprivation are thought to be additional cardiovascular disease risk factors that can accompany the more standard risks for hypertension, smoking, diabetes, and dyslipidemia [3]. Of particular concern is the lack of valid and reliable occupational exposures to toxic and carcinogenic materials firefighters encounter. Therefore, further studies need to be conducted to better identify specific firefighting occupational risk factors and inform the development of effective programs to lessen their effect.

Future mortality and morbidity research should include study designs and analysis plans that leverage available risk factor data for modeling and lead to a better understanding of the relationship between firefighting and health outcomes. Surveillance programs and registries, such as the Firefighter Cancer Registry Act of 2018 [81] will be important additions to future studies and monitoring the health of firefighters.

Table 1. Major Causes of Death: Firefighters and Non-Firefighters 1985-2013

Cause of Death (MAJOR)	# (%) Firefighters (n=2,818)	Non-firefighters (n=11,272)	**Total**
Cancer: malignant neoplasm	857 (30.4%)	3054 (27.1%)	3911
Malignant neoplasm of respiratory system	318 (11.3%)	1157 (10.3%)	1475
Malignant neoplasms of digestive organs and peritoneum	196 (7%)	719 (6.4%)	915
Malignant neoplasms of other and unspecified sites	124 (4.4%)	396 (3.5%)	520
Malignant neoplasms of male genital organs	75 (2.7%)	277 (2.5%)	352
Malignant neoplasms of lymphatic and hematopoietic tissue	71 (2.5%)	278 (2.5%)	349
Malignant neoplasms of urinary organs	50 (1.8%)	157 (1.4%)	207
Malignant neoplasms of buccal cavity and pharynx	21 (0.7%)	40 (0.4%)	61
Malignant neoplasms of breast	2 (0.1%)	19 (0.2%)	21
Malignant neoplasms of female genital organs	0 (0%)	11 (0.1%)	11
Diseases of the heart	824 (29.2%)	3338 (29.6%)	4162
Rheumatic heart disease, including fever	0 (0%)	13 (0.1%)	13
Hypertension with heart disease	17 (0.6%)	65 (0.6%)	82
Ischemic heart disease	619 (22%)	2512 (22.3%)	3131
Chronic disease of endocardium	13 (0.5%)	78 (0.7%)	91
Cardiomyopathy	40 (1.4%)	152 (1.3%)	192
Conductive disorder	57 (2%)	214 (1.9%)	271
Other diseases of the heart	78 (2.8%)	304 (2.7%)	382
Diseases of the respiratory system	278 (9.9%)	1173 (10.4%)	1451
Other diseases of the circulatory system	192 (6.8%)	946 (8.4%)	1138
Diseases of the digestive system	98 (3.5%)	373 (3.3%)	471
Disorders of the nervous system and sense organs	89 (3.2%)	352 (3.1%)	441
Diabetes mellitus	82 (2.9%)	335 (3%)	417
Other causes (residuals and blanks codes)	73 (2.6%)	301 (2.7%)	374
Diseases of the genito-urinary system	66 (2.3%)	250 (2.2%)	316
Violence	59 (2.1%)	224 (2%)	283
Transportation injuries	46 (1.6%)	179 (1.6%)	225
Mental, psychoneurotic, and personality disorders	45 (1.6%)	215 (1.9%)	260
Other injury	43 (1.5%)	226 (2%)	269
Symptoms and ill-defined conditions	21 (0.7%)	91 (0.8%)	112
Falls	13 (0.5%)	54 (0.5%)	67
Benign and unspecified neoplasms	11 (0.4%)	40 (0.4%)	51
Diseases of the blood and blood forming organs	11 (0.4%)	63 (0.6%)	74
Diseases of the musculoskeletal system and connective system	7 (0.2%)	32 (0.3%)	39
Diseases of the skin and subcutaneous tissue	2 (0.1%)	11 (0.1%)	13
Tuberculosis and HIV related disease	1 (0%)	15 (0.1%)	16
TOTAL	2818 (100%)	11272 (100%)	14,090

Table 2. Odds Ratios (OR) and 95% Confidence Intervals Based on Conditional Logistic Regression

Cause	# (%)		Odds Ratio	95% CI and p-value		
	Firefighters	Non-fighter		Lower	Upper	p-value
All malignant cancers	857 (30.4%)	3054 (27.1%)	1.19	1.08	1.3	0.0040
Malignant cancer of buccal cavity and pharynx	21 (0.8%)	40 (0.4%)	2.15	1.19	3.79	0.0108
Malignant cancer of other parts of the buccal cavity	6 (0.2%)	6 (0.1%)	4	1.07	14.96	0.0388
Malignant cancer of pharynx	13 (0.5%)	23 (0.2%)	2.26	1.05	4.65	0.0364
Malignant cancer of pancreas	46 (1.6%)	128 (1.1%)	1.45	1.01	2.06	0.0457
Malignant cancer of kidney	32 (1.1%)	70 (0.6%)	1.84	1.17	2.83	0.0086
Malignant cancer of other and unspecified sites	124 (4.4%)	396 (3.5%)	1.27	1.02	1.56	0.0318
Malignant cancer of connective tissue	10 (0.4%)	16 (0.1%)	2.5	1.01	5.86	0.0460
Malignant cancer of brain and other parts of the nervous system	30 (1.1%)	61 (0.5%)	1.98	1.23	3.12	0.0049
Other diseases of the circulatory system	192 (6.8%)	946 (8.4%)	0.8	0.68	0.94	0.0058
Cerebrovascular disease	126 (4.5%)	611 (5.5%)	0.82	0.67	0.996	0.0448
Accidental poisoning	7 (0.3%)	63 (0.6%)	0.43	0.16	0.95	0.0355

Conditional logistic regression models control matched factors
Ischemic heart disease: OR, 0.981; 95% CI, 0.885-1.108, p=0.7327

CHAPTER 3 CHANGES IN CARDIOVASCULAR RISK FACTORS AMONG NEWLY HIRED FIREFIGHTERS

Introduction

Cardiovascular disease (CVD) has been the leading cause of on-duty death among firefighters since 1977 [82, 83]. Current data show that approximately 40% of the line-of-duty fatalities in 2018 and 44% over the past decade were due to sudden cardiac death [84]. Estimates suggest an additional 17 to 25 non-fatal CVD events occurring among firefighters in the line-of-duty for each CVD fatality [31, 32]. Research shows that these events were triggered by the strenuous duties of firefighting [3, 33-37] and occurred among firefighters with underlying coronary heart disease [3, 33-35, 38, 41, 42] or structural heart abnormalities [3, 33, 37, 38, 41, 42]. In addition to the CVD health risks associated with the rigors of the occupation, firefighters often have elevated clinical and behavioral cardiovascular risk factors, including high blood pressure and cholesterol levels, inadequate levels of physical activity, poor nutrition, excess alcohol consumption and cigarette smoking [3, 33-35, 38, 40, 41, 44]. Moreover, 75% to 80% of firefighters are overweight; among those who are overweight, nearly 40% are obese [3, 38, 44, 49, 50], including fire service recruits [56, 57]. The effects of these risk factors are exacerbated by inadequate amounts of sleep, shift work, risk factor clustering, and stress [3]. The National Fire Protection Association 1582 (NFPA 1582) [85] provides recommendations for baseline and routine medical evaluations, fitness testing, and injury prevention programs to ensure that firefighters can safely perform job functions; however, annual examinations for firefighters are not mandatory in many United States fire departments. Candidate physical abilities tests (CPAT) and work performance evaluations (WPE) are also recommended to assure that both candidate and incumbent firefighters, respectively, can safely perform the essential functions of the firefighting job [86]. Due in part to the lack of clinical requirements for cardiometabolic health risk assessment, there are limited data and research on firefighters' cardiovascular risk factor profiles. Furthermore, studies focusing on the health status of firefighters in the first decade of their career are even more scarce. Thus, the purpose of this study was to examine the levels of traditional cardiovascular risk factors, including BMI, total cholesterol, HDL cholesterol, LDL cholesterol, and triglycerides, among new firefighters and determine the patterns of changes in these risk factors during the first five and ten years of their career.

Methods

Study population

Existing clinical data from a sample of newly hired firefighters were used for this study. Data were collected at Ascension Public Safety Medical, an occupational medical practice providing pre- and post-offer physical examinations for contracted fire departments in the Midwest, primarily in Indiana. Firefighters between 19 and 35 years of age [56] at the time of the pre-hire physical examination were included in this study (n=1,255). Among these 1,255 unique firefighters, there were 903 at baseline, 704 at five years and 591 at 10 years included in the analysis. Applicants older than 35 years of age were excluded due to limited information for determining if these individuals were new to the profession or existing firefighters seeking employment at a different fire department. Consent for the use of the data for research purposes was obtained at the time of the physical examination. This study was approved by Indiana University Office of Research Compliance (Protocol #2002167025).

Study data

Independent Variables

Demographic Data

Demographic data included age in years at the time of pre-hire physical examination, sex, and race. Firefighters' sex was recorded as male or female. Race was most parsimoniously analyzed as a dichotomous variable (white or not white) because 84.6% of firefighters reported that they were white, 11.3% were African American, 1.4% were Hispanic and for 2.0% their race was unknown. Ethnicity of the firefighter was not reported separately from race.

Dependent Variables

Clinical Risk Factors

Clinical risk factors included in the analyses were BMI, total cholesterol, HDL cholesterol, LDL cholesterol, and triglycerides (TG). Body mass index (BMI) was computed using the standard computation: weight (kilograms)/height $(\text{meters})^2$ [87]. Cholesterol and triglyceride levels were measured and provided by the clinical laboratory.

Clinical Evaluations

The pre-hire physical examination date was used to determine baseline and follow-up dates for inclusion in the study. Baseline was defined as clinical data collected during either the pre-hire physical examination or in the first post-hire department examination up to 18 months after the pre-hire physical examination date. Clinical data were collected during five-year follow-up defined as occurring during the physical examination approximately five years (54-66 months) after the pre-hire physical examination date, and ten-year follow-up defined as occurring during the physical examination approximately ten years (114 to 126 months) after the pre-hire date. There was variation in scheduling the physical examination from year to year due to missed appointments related to fire and emergency calls, training, change in job assignment, schedule rotations, sick days, paid time off and other departmental responsibilities. The fitness evaluation, which occurred on the same day as the physical examination, included the assessment of height and weight used to compute BMI. Blood draws for laboratory analysis occurred approximately three weeks prior to the physical examination date.

Statistical analysis

<u>Frequency and Cross Tabulation Analysis</u>

Data were analyzed using SPSS Version 25 (IBM Corp, Armonk, NY) [69]. Frequencies for categorical variables and means for continuous variables were computed at each time point. Linear mixed-effects models were used to evaluate changes in each of the five CVD risk factors over three-time points (baseline, five years, and ten years after the pre-hire date). Age in years at the time of the pre-hire physical examination, sex, and race were included in each model as covariates to control for potential confounding.

Triglyceride levels were not normally distributed; therefore, a natural logarithm (ln) transformation of this variable was included in the model. Exponentiated values for the natural logarithm estimates of TG were shown in tables and figures to facilitate interpretation. Statistical significance for the Wald statistics was defined as $p<0.05$ for all tests. Age, BMI, total cholesterol, HDL cholesterol, LDL cholesterol, and TG values were used as continuous variables in the models. These measures were also re-coded into categorical variables for the descriptive analyses. Age was re-coded into 19.0-19.9 years, 20.0-29.9 years and 30.0 to 34.9 years of age. BMI was defined using standard Centers for Disease Control and Prevention [88] categories. Underweight was defined as <18.5 kg/m^2, normal weight as 18.5-24.9 kg/m^2, overweight as 25.0-29.9 kg/m^2 and obesity as 30 kg/m^2 or higher. National Heart, Lung, and Blood Institute, National Cholesterol Education Program ranges were used to define total cholesterol, HDL cholesterol, LDL cholesterol and TG levels in Table 3 [89].

Results

Characteristics of the firefighters at baseline are shown in Table 4. Among the nine hundred three (n=903) firefighters included at baseline, most were white (85.5%), males (94.1%) and under 30 years of age (69.4%). The mean firefighter age was 27.8 years. Regarding risk factors, most (50.5%) new firefighters were overweight (BMI 25.0-29.9 kg/m^2). An additional 26.2% of firefighters were obese (BMI $\geq$30.0 kg/m^2). Mean BMI at baseline was 27.9 kg/m^2. Nearly three-quarters of firefighters (73.6%) had desirable total cholesterol measures (<200 mg/dl). About one-fifth (21.6%) of firefighters at baseline had borderline high (200-239 mg/dl) and five percent (4.8%) had high total cholesterol ($\geq$240 mg/dl). Mean total cholesterol was 179.0 mg/dl. Most (76.1%) new firefighters had healthy HDL cholesterol (>40 mg/dl males, >50 mg/dl females) (mean HDL 48.5 mg/dl); however, more than half (57.8%) had LDL cholesterol measures that were not optimal ($\geq$100 mg/dl) (mean LDL cholesterol 108.8 mg/dl). Eighty percent (80.2%) of new firefighters had healthy triglyceride levels at baseline (mean 95.3 mg/dl).

Cardiovascular risk factor trends

Body mass index (BMI), total cholesterol, LDL cholesterol and TG measures increased significantly ($p<0.001$ for all linear trends) while HDL cholesterol measures decreased ($p<0.001$) over time (Table 5, Figures 2-6). Mean BMI levels at baseline, 5 years follow-up and ten years follow-up adjusting for age, sex, and race were 26.7, 27.7, and 28.6 kg/m^2, respectively. An examination of temporal changes showed a 3.5% increase in BMI among new firefighters from baseline to 5 years follow-up ($p<0.001$) and 6.8% increase from baseline to ten years follow-up ($p<0.001$) (Figure 1). The mean total cholesterol values for firefighters at baseline, 5 years follow-up and ten years follow-up were 177.3, 184.3, and 193.3 mg/dl, respectively. There was a 4.0% increase in mean total cholesterol among new firefighters from baseline to 5 years follow-up ($p<0.001$) and 9.1% increase from baseline to ten years follow-up ($p<0.001$) (Figure 2). Adjusted least-square mean values at baseline, 5 years follow-up and ten years follow-up were 102.8, 108.0, and 117.0 mg/dl for LDL cholesterol, 76.7, 83.0, and 88.9 mg/dl for TG, and 57.6, 57.1, and 55.4 mg/dl for HDL cholesterol, respectively. There was a 5.0% increase in LDL cholesterol among new firefighters from baseline to 5 years follow-up ($p<0.001$) and 13.7% increase from baseline to ten years follow-up ($p<0.001$) (Figure 3). The overall P-value for time trend showed a significant ($p<0.001$) increase in TG over time. Mean TG increased 8.2% from baseline to 5 years follow-up ($p<0.001$) and 15.9% increase from baseline to 5 years follow-up ($p<0.001$) (Figure 4). HDL-cholesterol decreased significantly over time. Mean HDL cholesterol decreased 0.8% from baseline to 5 years follow-up ($p<0.001$) and 3.8% from baseline to ten years follow-up ($p<0.001$) (Figure 5).

Discussion

This study found that cardiovascular risk factors increased early in firefighters' careers. New firefighters' BMI, total cholesterol, LDL cholesterol, and TG levels increased significantly, while HDL cholesterol levels decreased significantly as early as five years of being on the job. These unfavorable cardiovascular risk profiles continued to worsen in the tenth year of their firefighting careers.

To date, this is the first study to examine trajectories in traditional CVD risk factors among newly hired firefighters over a ten-year period of time. The results of this study were consistent with those from earlier studies that found relationships between risk factor prevalence and line-of-duty cardiovascular events and early retirements. Those studies showed that firefighters experiencing sudden cardiac deaths and CVD retirements had statistically higher levels of CVD risk factors [35, 40, 41]. Other studies of firefighters at all ages showed elevated prevalence of CVD risk factors among this occupational group [35, 50, 90-94]. While studies of firefighters during the last decade have advanced our understanding of cardiovascular disease among firefighters; little is known about how firefighters' lifestyle and behaviors affect their health. It is likely that the firehouse culture of eating a poor diet [58-60, 95], eating large serving sizes [62], having unreliable meal times along with inadequate amounts of physical activity as well as sleep disruptions and deprivation [36] contribute to the increased CVD risk factors among firefighters as was found in this study. These lifestyle and cultural behaviors, especially as new firefighters are starting their careers, including the influence of their crews and relationships in the fire service, may be related to the shift towards increased CVD risk in a little as five years into the occupation. According to Staley, Winder and

Linnan (2011) cardiovascular disease was perceived as a risk among older firefighters; however, they found this was not the case among new and younger firefighters [95].

A strength of this study was the large sample size, which provided adequate power to assess the independent effects of time while controlling for demographic covariates on CVD risk in new firefighters over an estimated ten-year period. Body mass index (BMI) was determined by height and weight of firefighters in light clothing and measured by trained and experienced fitness professionals, avoiding biases associated with self-report of lower weight and increased heights. Another strength of this study included the use of linear mixed models to examine trajectories of these risk factors over time. This robust technique includes all available data in the analysis for each participant instead of excluding a participant's data when only a single piece of data was missing.

This study also has limitations. This study sample consisted of newly hired firefighters from departments contracted for physical examinations within a single occupational medical practice, which may limit the generalizability of the findings to the national firefighter population. More studies of new firefighters need to done to confirm the results. Until now, research targeted incumbent firefighters leaving a gap in knowledge regarding applicant or early-career firefighter health. While the representativeness of this study is not exactly known, it is the first study on health trends among new Indiana firefighters. Future comprehensive chronic disease and risk factor surveillance studies should include a baseline set of health indicators as early in the firefighter's career as possible. Furthermore, the small amount of variation in sex and race also prevented robust sub-group analyses. Investigators were not able to determine if newly hired firefighters older than 35 years of age were new to the profession or existing firefighters who were seeking employment in a different fire department and were required to take a pre-employment physical. Consequently, firefighters, some of whom may actually have been new to the firefighting profession, were excluded from the analysis. Likewise, some of those younger than 36 who were taking the pre-employment physical may have been transferring from another fire department and not new to the profession. The study utilized a limited set of conventional cardiovascular risk factors because they are routine clinical measures and are most relevant to cardiometabolic health. Although total, HDL, and LDL cholesterol levels changed significantly in the unhealthy direction, this study did not have access to the firefighters' use of lipid-lowering medication and therefore, the investigators were not able to adjust for this potential confounder or exclude these participants to examine the relationship between untreated lipid levels and time. Occupational and behavioral risk factors were not available for inclusions in this study.

Finally, BMI, a practical anthropometric measure used as a surrogate to evaluate overall adiposity, cannot distinguish between lean and fat mass potentially resulting in misclassification of firefighters body composition status. While recent studies showed significant correlations between the proportion of firefighters classified as obese by BMI, percent body fat and waist circumference [55, 96, 97], studies reported varying rates (3%-29% and 5%-59%) of false positives and false negatives (22%-35% and 5%-27%) when comparing body mass index categories to similar percent body fat and waist circumference categories, respectively [55, 96-98]. Misclassification of firefighters with healthy or optimal body composition by measures of percent body fat or waist circumference measures as overweight by BMI and those classified as normal weight by

BMI, but in at risk categories by percent body fat or waist circumference will lead to an under-estimation of risk associated with increasing body fat. Even though BMI is a convenient method for estimating overweight and obesity, it may not be a reliable tool for assessing health status among firefighters. Given that body composition is an important health risk indicator for a firefighter, future research should include the most reliable and practical measures of central adiposity.

Clinical Implications

Given the considerable evidence linking cardiovascular risk profiles of firefighters to their risk of cardiovascular events, attention needs to be focused on the development of effective health promotion programs in the fire service. This study supports the need to start these programs as early as recruit school among career firefighters. Firefighters, due their occupational exposures, are part of a vulnerable population that should be considered at risk and should therefore follow a more aggressive screening and treatment schedule. It is also important to educate clinicians, specifically primary care providers, to better manage the CVD risk factors of this population. Primary care providers may not be fully aware of the risks of firefighting and the potential need for CVD risk factor screening and aggressive intervention in addition to using preventive strategies earlier among firefighters than the standards set for the general population.

Conclusion

This study found that newly hired firefighters' body mass index, total cholesterol, LDL cholesterol and triglycerides levels increased significantly, while HDL cholesterol levels decreased significantly as early as five years after being on the job. The findings indicate that future resources need to be dedicated to delivering health interventions, including annual medical surveillance and education programs, to firefighters early in their career to reduce their future risk of cardiovascular disease morbidity and mortality.

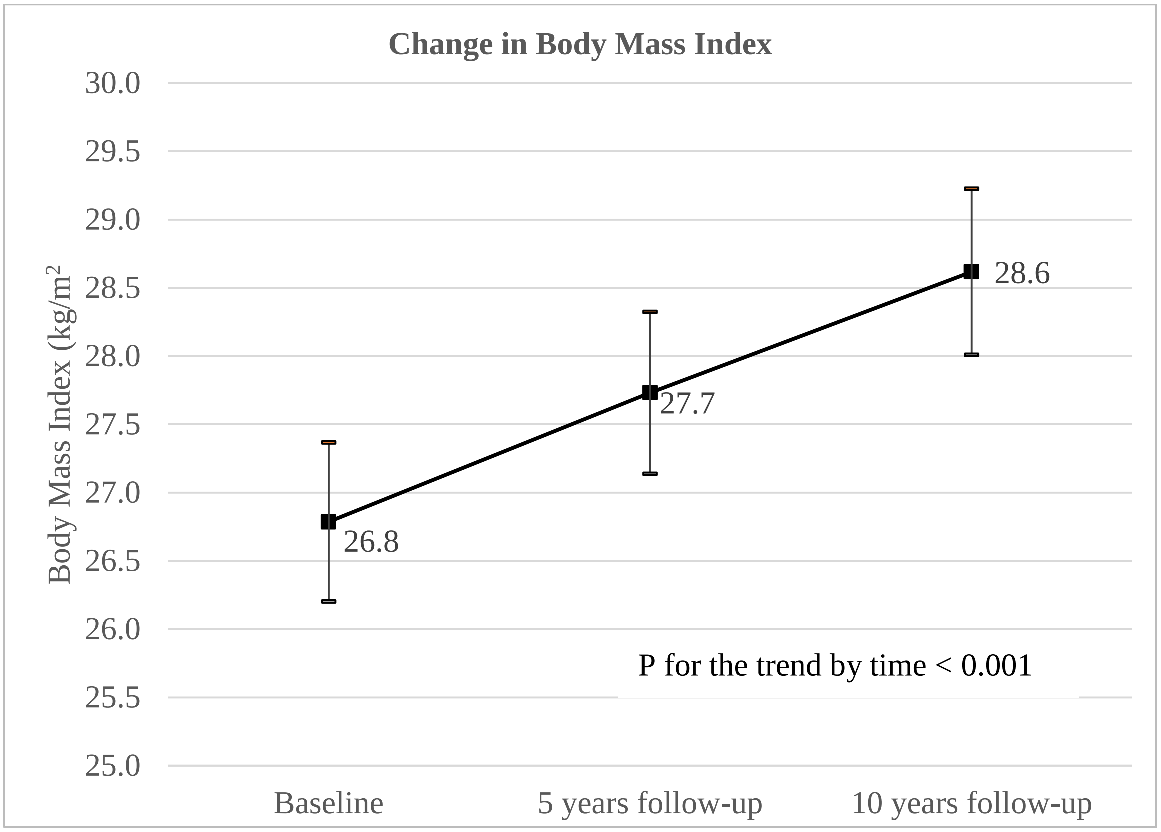
Table 3. National Heart Lung, and Blood Institute, National Cholesterol Education Ranges for Cholesterol and Triglycerides for Adults

Total Cholesterol Categories (mg/dl)	
Desirable	<200
Borderline High	200-239
High	≥240
HDL Cholesterol Categories (mg/dl)	
Normal males	≥40
Normal females	≥50
At Risk males	<40
At risk females	<50
LDL Cholesterol Categories (mg/dl)	
Optimal	<100
Near Optimal	100-129
Borderline High	130-159
High	160-189
Very High	≥190
Triglyceride Categories (mg/dl)	
Normal | Healthy	<150
Borderline High	150-199
High	200-499
Very High	>500

Table 4. Baseline Characteristics of Firefighters (n=903)

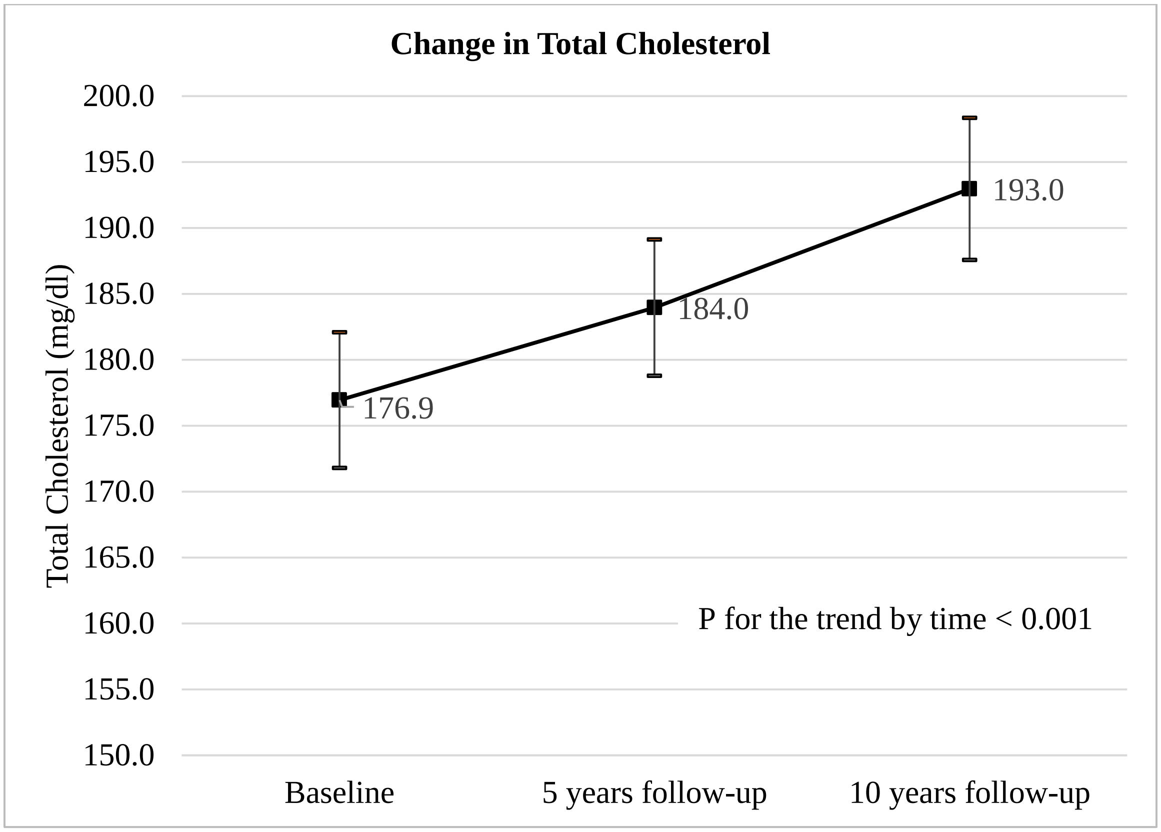
Characteristic	# (%)/Mean (SD)
Age in Decades (n=903)	
19.0-19.9	1 (0.1%)
20.0-29.9	626 (69.3%)
30.0-39.9	276 (30.6%)
Age Mean (SD)	27.8 (3.7)
Sex (n=903)	
Male	850 (94.1%)
Female	53 (5.9%)
Race (n=894)	
White	764 (85.5%)
Other	130 (14.5%)
Body Mass Index (kg/m2) (n=894)	
Underweight (< 18.5)	1 (0.1%)
Optimal (18.5-24.9)	207 (23.2%)
Overweight (25.0-29.9)	452 (50.5%)
Obese (> 30)	234 (26.2%)
Missing	9
BMI Mean (SD)	27.9 (4.1)
Total Cholesterol (mg/dl) (n=607)	
Desirable (<200)	447 (73.6%)
Borderline High (200-239)	131 (21.6%)
High (>EQ 240)	29 (4.8%)
Missing	296
Mean (SD)	179.0 (34.6)
HDL Cholesterol (mg/dl) (n=607)	
Normal| Healthy (>40 males, >50 females)	464 (76.1%)
At Risk (<40, <50 females)	143 (23.9%)
Missing	296
Mean HDL (SD)	48.5 (12.3)
LDL Cholesterol (mg/dl) (n=600)	
Optimal (<100)	253 (42.2%)
Near Optimal(100-129)	202 (33.7%)
Borderline High (130-159)	114 (19%)
High (160-189)	24 (4%)
Very High (>190)	7 (1.2%)
Missing	303
Mean LDL (SD)	108.8 (31.0)
Triglycerides (mg/dl) (n=607)	
Normal | Healthy (<150)	487 (80.2%)
Borderline High (150-199)	63 (10.4%)
High (200-499)	54 (8.9%)
Very High (> 500)	3 (0.5%)
Missing	296
Mean Trig (SD)	111.4 (75.721)

Figure 2. Change in Mean Body Mass Index at Baseline, 5 years Follow-Up and 10 Years Follow-Up



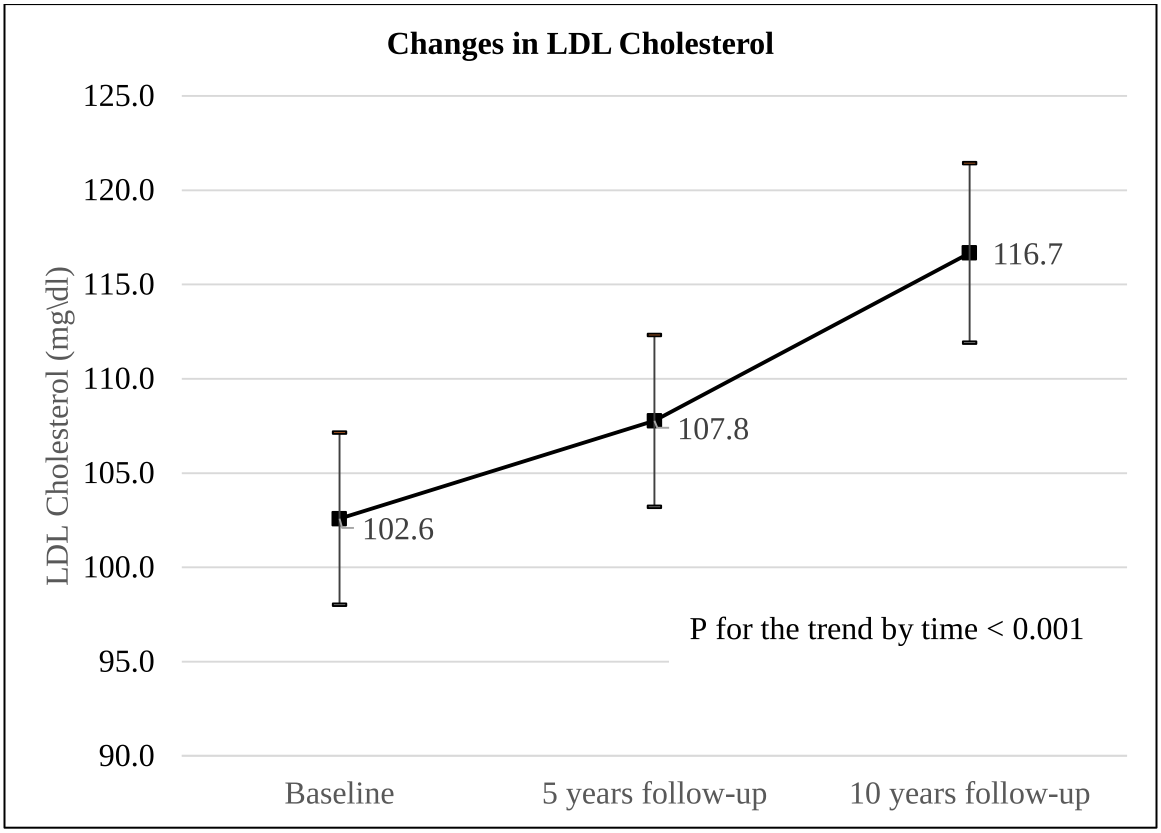
Model was adjusted for firefighters' age (continuous), sex (male or female), and race (white or non-white). Time is a categorical variable (baseline, 5-year follow-up, and 10-year follow-up); baseline is the reference category.

Figure 3. Change in Mean Total Cholesterol at Baseline, 5 Years Follow-Up and 10 Years Follow-Up



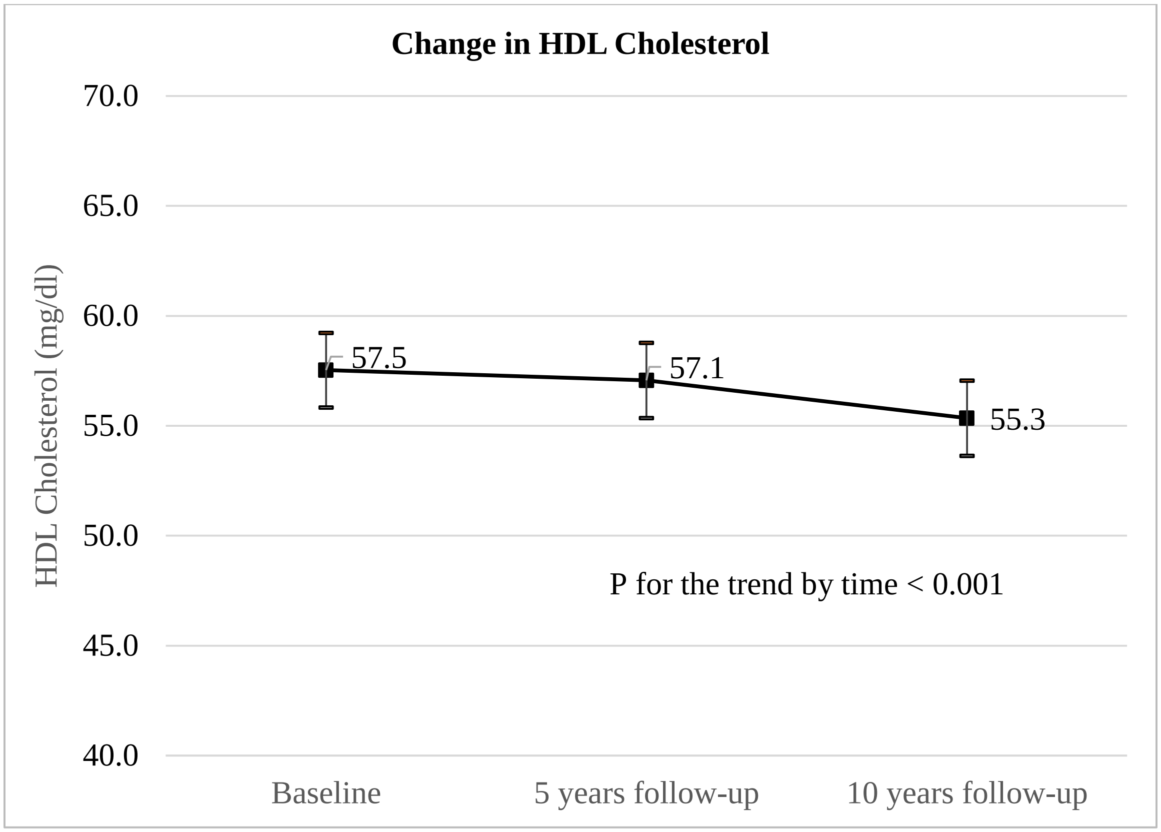
Model was adjusted for firefighters' age (continuous), sex (male or female), and race (white or non-white). Time is a categorical variable (baseline, 5-year follow-up, and 10-year follow-up); baseline is the reference category.

Figure 4. Change in Mean LDL Cholesterol at Baseline, 5 Years Follow-Up and 10 Years Follow-Up



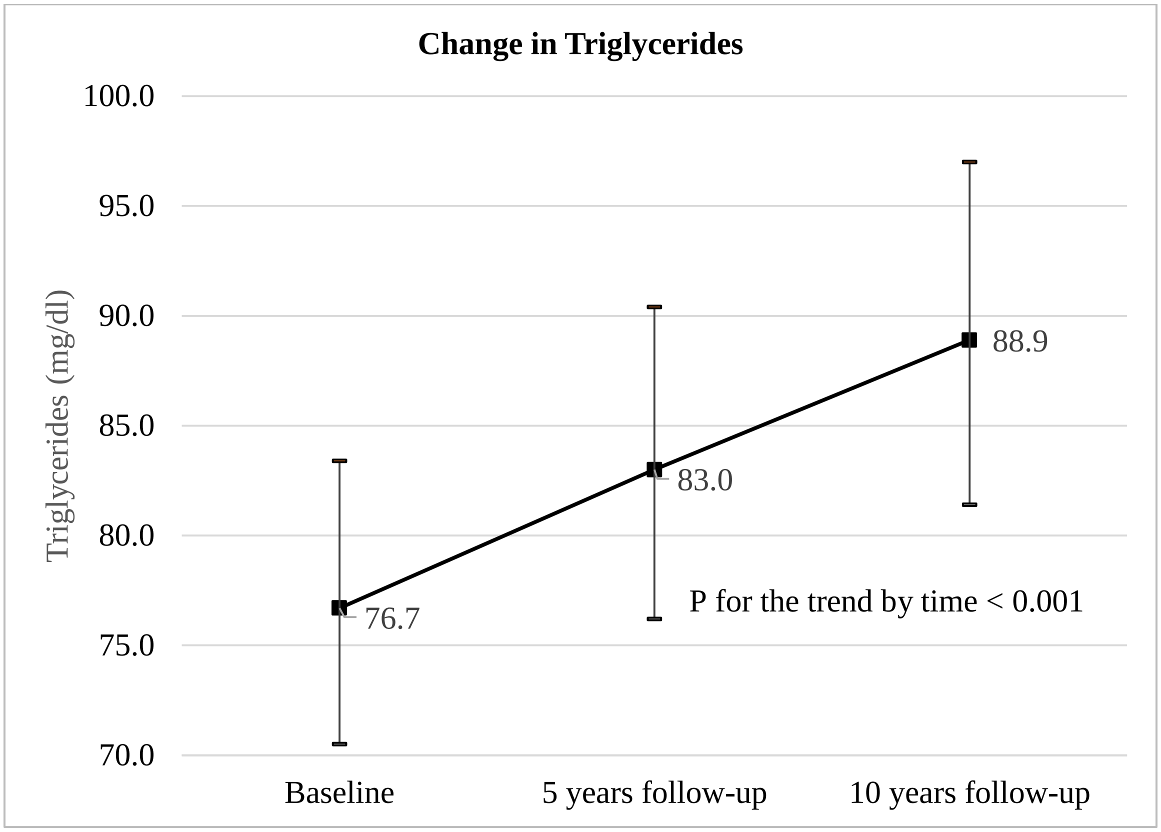
Model was adjusted for firefighters' age (continuous), sex (male or female), and race (white or non-white). Time is a categorical variable (baseline, 5-year follow-up, and 10-year follow-up); baseline is the reference category.

Figure 5. Change in Mean HDL Cholesterol at Baseline, 5 Years Follow-Up and 10 Years Follow-Up



Model was adjusted for firefighters' age (continuous), sex (male or female), and race (white or non-white). Time is a categorical variable (baseline, 5-year follow-up, and 10-year follow-up); baseline is the reference category.

Figure 6. Change in Mean Triglycerides at Baseline, 5 Years Low-Up and 10 Years Follow-Up



Model was adjusted for firefighters' age (continuous), sex (male or female), and race (white or non-white). Time is a categorical variable (baseline, 5-year follow-up, and 10-year follow-up); baseline is the reference category.

Table 5. Linear Mixed Models for Repeated Measures Collected at Baseline, 5 Years and 10 Years of Follow-up: Change over time in Five Cardiovascular Disease Risk Factors

		5-Year follow-up versus baseline				10-Year follow-up versus baseline			
	Overall			95% CI				95% CI	
Dependent Variable	p-value	b (S.E.)	p	Lower	Upper	b (S.E.)	p	Lower	Upper
Body Mass Index	<0.001	0.945 (0.089)	<0.001	0.771	1.12	1.832 (0.110)	<0.001	1.616	2.049
Total Cholesterol	<0.001	7.017 (1.302)	<0.001	4.459	9.574	16.072 (1.676)	<0.001	12.781	19.363
Triglycerides (log)	<0.001	0.079 (0.025)	0.002	0.03	0.127	0.147 (0.028)	<0.001	0.092	0.202
HDL-C	<0.001	-0.463 (0.453)	0.307	-1.352	0.426	-2.167 (0.503)	<0.001	-3.154	-1.179
LDL-C	<0.001	5.178 (1.207)	<0.001	2.808	7.549	14.126 (1.515)	<0.001	11.15	17.101

All models were adjusted for firefighters' age (continuous), sex (male or female), and race (white or non-white)*
Time is baseline, 5-year follow-up and 10 year follow-up
Each row is a different model. All models were adjusted for firefighters' age (continuous), sex (male or female), and race (white or non-white). Dependent variable = cardiovascular disease risk factor.
b = the change in mean from baseline to either 5-year or 10-year follow-up time point.
Time is a categorical variable (baseline, 5-year follow-up, and 10-year follow-up); baseline is the reference category.
Overall= Overall Time Trend

CHAPTER 4 BARRIERS TO WEIGHT MANAGEMENT AMONG OVERWEIGHT AND OBESE FIREFIGHTERS

Introduction

Firefighting is a dangerous occupation. Each shift day, firefighters work in stressful conditions putting themselves at risk for physical and psychological harm [29, 99-101]. In 2017, there were more than 1.1 million firefighters in the United States [102]. Over one-third (35%) of these first responders were career firefighters, while 65% were volunteers [102]. An estimated 77,900 (7.0%) of these firefighters were women. Just over half were 30 to 49 years of age [102]. Most career firefighters (72.0%) protect communities with 25,000 or more citizens; 95.0% of volunteers serve communities with less than 25,000 people [102]. Surveillance shows that cardiovascular disease (CVD), usually myocardial infarction, has been the most common cause of line-of-duty death among US firefighters since 1997, accounting for 45% of all deaths on the fire grounds [82, 83]. Current data indicate that 44% [84] of the line-of-duty fatalities in 2018 and 44% over the past decade were due to CVD [84]. Furthermore, there are as many as 25 non-fatal CVD events occurring in the line-of-duty for every CVD fatality [31, 32]. These CVD events are triggered by the strenuous duties and environmental exposures associated with fire suppression [3, 33-36] and occur among firefighters with underlying coronary heart disease [3, 33-35, 38, 41], structural heart abnormalities [3, 33, 37, 38, 41], or elevated cardiovascular risk factors [3, 33-35, 38, 40, 41, 44].

Obesity is a well-established risk factor for CVD [33, 45-47] and other chronic conditions, including cancer [103], sleep apnea [47], and metabolic syndrome [47]. Obesity is also known to increase the burden of existing CVD risk factors by promoting the negative effects of blood pressure, lipids, glucose metabolism, sleep related breathing problems, and cardiac enlargement through clustering [45, 48, 49]. Among firefighters, overweight and obesity are adversely related to cardiovascular risk profiles [34, 35, 40, 44, 49-51], lower levels of cardio-respiratory fitness [3, 38], metabolic syndrome [3, 38], coronary heart disease (CHD) [52], on-duty CHD events and death [40], injury [53], disability[54], and CVD-related retirements [40]. Obesity and obesity-related health conditions such as metabolic syndrome, hypertension, and sleep apnea are also associated with an increased risk of CHD and structural heart abnormalities such as cardiomegaly, further increasing risk through multiple pathways [34]. Despite these serious health risks, 75% to 80% of firefighters have been found to be overweight (body mass index [BMI] more than or equal to 25kg/m^2); among those firefighters who were overweight, up to 40% were obese (body mass index [BMI] more than or equal to 30) [3, 44, 49-51], including fire service recruits [56, 57].

Obesity continues to be an ongoing health problem for the fire service [3]. In the United States, 35% of adults are overweight and 31% are obese. In Indiana, 32% are overweight and 34% of adults are obese [104]. There are approximately 1.9 billion adults who are overweight worldwide [105]. Other health behaviors and clinical conditions such as inadequate levels of physical activity, smoking, poor nutrition including excess alcohol consumption, hypertension, dyslipidemia, and occupational hazards are independent risk factors that likely interact to adversely affect the cardiovascular health of the firefighter [3, 38].

The understanding of health risks associated with overweight and obesity among firefighters [62] has improved over the last decade; however, little is known about the day-to-day obstacles firefighters face to manage their weight. Available evidence shows that diets high in fast food, sugary drinks [58], refined carbohydrates and saturated fats [58-60], accompanied by firehouse traditions of large portion sizes and second helpings [61, 62] may contribute to the problem. The higher cost of healthy food, additional time needed for healthy meal preparation, and lower levels of social support for dietary change at home and in the firehouse have also been identified by firefighters as challenges to improving eating behaviors [62, 63].

While these studies provide the foundation for understanding factors that influence overweight and obesity among firefighters, the sample sizes and methodologies used limited the generalizability of results to the larger fire service population. Thus, additional research is needed to identify common challenges firefighters face for adopting healthy eating behaviors and to inform the development of targeted interventions to support healthy weight management in order to mitigate risk for CVD events. The purpose of this study was to examine barriers toward weight management identified by firefighters from a predetermined response list on a standard health risk appraisal (HRA) and explore how these barriers might be related to age, sex, readiness for change, level of physical activity, fruit and vegetable consumption, body weight status, cigarette smoking, or binge drinking. This study is unique in that it included one of the only known set of quantifiable metrics on barriers to weight management and readiness for change among firefighters described in the literature. Furthermore, this study, unlike previous research on health topics, included female firefighters in the analysis.

Methods

A convenience sample of existing health risk appraisal data on 2,373 firefighters was used for this study. Data were collected at Ascension Public Safety Medical, an Indiana-based occupational medical practice at the time of annual physical examinations provided by nurse practitioners during the period 2012 to 2016. Overweight firefighters who described their readiness for change toward weight management status as "ready to begin a weight management program'' or ''currently working toward a healthier weight" were included in the analysis. Health risk appraisal (HRA) data for two firefighters with body weights greater than 700 pounds were excluded from the study since these values were assumed to be data entry errors. Consent for the use of data for research purposes was obtained at the time of the physical examination. This study was approved by Indiana University Office of Research Compliance (Protocol #1605861649).

Study variables

<u>Independent Variables</u>

Demographic Data

Demographic data included sex and age in years at the time of the physical examination. Age as a continuous variable was used in the modeling analyses. Age was also coded into three categories for the descriptive analyses: 19 to 39 years, 40 to 49 years, and 50 or more years of age.

Readiness for Change

Three thousand five hundred sixty two (n= 3,562) overweight or obese firefighters were asked to identify their readiness for change from a list of five response options: (1) "my weight is healthy: I do not need a weight management program," (2) "I am currently working toward a healthier weight, but still face the barriers selected below (currently working toward a healthier weight)," (3) "I am ready to begin a program of weight management, but face the barriers selected below (ready to begin a weight management program)," (4) "I am thinking about trying to lose weight, but am not ready to commit to the changes required," and (5) "losing weight might be beneficial, but I am not seriously considering a commitment to weight loss at this time." Firefighters (n=2,373) who selected ''currently working toward a healthier weight" or "ready to begin a weight management program"' were included in the analysis. Other response options in the readiness for change item contained a skip pattern omitting the identification of barriers toward weight management; therefore, these cases (n=1,189) were excluded from the analysis.

Health Risk Factors

Health risk factors included in the analyses were physical activity, fruit and vegetable consumption, body mass index, smoking, and binge alcohol consumption status.

Physical Activity Status

Firefighters were categorized as meeting or not meeting the federal physical activity recommendation using exercise frequency and intensity items on the HRA [106, 107]. Firefighters meeting the recommended amount of at least 150 minutes of moderate intensity aerobic physical activity per week were classified as meeting the requirement.

Fruit and Vegetable Consumption Status

Food frequency and serving size items on the HRA were used to determine if firefighters met or did not meet the federal recommendation for daily fruit and vegetable consumption [108]. Firefighters meeting the consumption of 5-per-day servings of fruit and vegetable recommendation were classified as meeting the requirement.

Body Mass Index Status

Firefighters were categorized as overweight or obese using the standard computation of body mass index (BMI): weight (kgs)/ meters^2 [87].

Cigarette Smoking Status

Firefighters were identified as not a current cigarette smoker or current cigarette smoker based on their response to an item on the HRA describing their cigarette smoking behavior. Firefighters who reported that they "currently smoke" were classified as current cigarette smokers. Those who never smoked or quit smoking prior to completing the health risk appraisal were classified as not a current cigarette smoker.

Binge Alcohol Drinking Status

Firefighters were categorized into a no binge drinking in the past month or any binge drinking in the past month category based on their response to an item on the HRA asking the firefighter to describe "how many times (if any) have you had five or more drinks on one occasion'' in the past month? Firefighters reporting ''none'' were classified as ''no binge drinking in the past month.'' Firefighters reporting one or more times were classified as ''any binge drinking in the past month [109].''

<u>Dependent Variables</u>

Barriers to Weight Management (Barriers)

Overweight and obese firefighters were asked to identify their ''barriers to weight management'' from the following predetermined list of five response options on the health risk appraisal questionnaire: (1) lack of knowledge about weight management (lack of knowledge), (2) lack of access to low-calorie or healthy foods, (3) family or social group won't like or support a change, (4) lack of access to exercise opportunities, and (5) eating helps me cope with stress so restricting foods could make my life more stressful (eating helps me cope with stress). A summary index variable, barriers burden, was computed by summing the total number of barriers selected by each firefighter. This index variable was most parsimoniously analyzed as a dichotomous variable (no barriers vs one or more barriers) because 37% of firefighters identified zero barriers and an additional 59% reported one barrier. Approximately 4% of firefighters reported two barriers and less than 1% reported three to five barriers toward weight management.

Statistical analysis

Frequency and Cross Tabulation Analysis

Data were analyzed using SPSS Version 25 (IBM Corp, Armonk, NY)[69]. Fisher's exact probability tests were used to compare the frequencies of categorical variables by sex prior to model selection. The independent samples t-test was used to compare the distributions of continuous variables, including ages.

Model Selection

Univariate and multivariate-adjusted logistic regression models for each barrier and the index variable, barriers burden, were used to identify potential predictors (Figure 7). Predictors in either the unadjusted or adjusted models with P-values for the Wald statistic less than 0.25 were allowed into initial multivariable models. Predictors with P-values (Wald) less than 0.10 were retained to develop the main effects models. The alpha of less than 0.25 was used for variable selection to ensure potential multivariable effects would not be overlooked, and alpha of less than 0.10 was used for the final variable retention since exploring barriers to weight management identified by firefighters was more important to future research than the risk of identifying Type I errors [110, 111]. Age and sex were forced into all the models to control for potential confounding. Two-way interaction terms for all predictors in the main effect models were tested separately.

Those with P-values (Wald) less than 0.10 were included in the final models [112]. Diagnostics to examine final models for outliers as well as to test assumptions for linearity and multicollinearity were assessed on each model. Sensitivity analyses were conducted on models by excluding cases with standardized residuals outside of $\pm$1.96 to determine if excluding cases affected the findings.

Results

Most of the 2,373 firefighters in this study were men (94.4%) between the ages of 40 to 49 years (men 38.5%; women 45.1%). The proportion of female firefighters (5.6%) was similar to those reported by the National Fire Protection Association (4.6%) [113]. Male and female firefighters did not differ by age (mean 44.3; 19 to 78 years) or readiness for change toward weight management. However, more female firefighters were overweight (56.4% women vs 40.2% men), while more men were obese (59.8% men vs 43.6% women).

Regarding risk factors (Table 6), most overweight or obese men (83.6%) and women (78.9%) were currently working toward a healthier weight. Also, most of the men (72.4%) and women (65.3%) reported meeting the federal guideline for physical activity. Significantly more women reported eating five fruits and vegetables daily (42.1% women vs 25.2% men) and no binge drinking in the past 30 days (74.2% women vs 59.2% men).

Significantly more men (94.8%) were not current cigarette smokers compared with women (89.5%).

Prevalence estimates for barriers to weight management

Lack of knowledge about weight management was the most commonly identified barrier to weight management. Significantly more men (19.0%) reported ‘‘lack of knowledge about weight management’’ compared with women (11.3%) ($p=0.028$). More women (24.8%) than men (13.6%) reported ‘‘eating helps me cope with stress so restricting foods could make my life more stressful’’ ($p<0.001$). Men and women did not differ significantly in the identification of ‘‘lack of access to low-calorie or healthy foods,’’ (17.9% and 13.5%, respectively), ‘‘family or social group won’t like or support a change,’’ (7.0% and 10.5%, respectively), or ‘‘lack of access to exercise opportunities’’ (11.3% and 12.8%, respectively) as barriers to weight management, nor was there a difference in the total number of barriers selected for male firefighters compared with female firefighters. Most men (63.0%) and women (65.4%) selected one or more barriers to weight management.

Lack of knowledge about weight management (lack of knowledge)

Firefighter sex, readiness for change, and smoking status significantly contributed to the likelihood that firefighters identified ‘‘lack of knowledge’’ as a barrier to weight management. Overall, the final adjusted model showed female firefighters (OR, 0.503; 95% CI, 0.289-0.877; $p=0.015$) and non-smokers (OR,0.686; 95% CI, 0.450-1.045; $p=0.079$) were less likely than men and current cigarette smokers to choose ‘‘lack of knowledge’’ as a barrier for weight management. Firefighters who reported they were ready to begin a weight management program (OR, 8.719; 95% CI, 2.605-29.185; $p<0.001$) were nearly nine times more likely to choose ‘‘lack of knowledge’’ as a barrier for weight management compared with those who were currently working toward a healthier weight. However, the effect of ‘‘ready to begin a weight management program’’ was qualified by an interaction with age ($p=0.023$). Overall, firefighters who were ready to begin a weight management program were more likely to identify ‘‘lack of knowledge’’ as a barrier to weight management compared with firefighters who were currently working toward a healthy weight. While this effect was the same for all firefighters, it was stronger for 30-year-old firefighters (OR=3.442) compared with 60-year-old firefighters (OR=1.358) when controlling for sex and cigarette smoking. Body mass index, physical activity, binge drinking, and fruit and vegetable consumption status were not associated with the firefighter’s selection of ‘‘lack of knowledge’’ as a barrier toward weight management (Table 7).

Lack of access to low-calorie or healthy foods

Age, binge drinking, and fruit and vegetable consumption status significantly contributed to the likelihood that firefighters identified ‘‘lack of access to low-calorie or healthy food’’ as a barrier to weight management as shown in the final adjusted model. Older firefighters (OR, 0.975; 95% CI, 0.964-0.987; $p< 0.001$), as well as those who reported no binge drinking in the past month (OR, 0.800; 95% CI, 0.644-0.995; $p=0.044$) and those who met the guidelines for fruit and vegetable consumption (OR, 0.715; 95% CI, 0.553-0.925; $p=0.011$) were less likely to identify ‘‘lack of access to low-calorie or healthy food’’ as a barrier to weight management. Sex, readiness for change, body mass index, physical activity, and smoking status were not associated with the firefighter's identification of ''lack of access to low-calorie or healthy food'' as a barrier to weight management (Table 8).

Family or social group won't like or support a change

There were no candidate predictor variables that met the criteria for the final adjusted model for this barrier. The Wald P-value for each predictor was not significant for either the bivariate unadjusted or adjusted multivariable model. Thus, there were no relationships between reporting ''family or social group won't like or support a change'' as a barrier to weight management and demographic data or key risk factors. Age and sex were not significant, although they were forced into the model (Table 9).

Lack of access to exercise opportunities

Readiness for change and physical activity status significantly contributed to the likelihood that firefighters identified ''lack of access to exercise opportunities'' as a barrier to weight management. In the final adjusted model, firefighters who were ready to begin a weight management program (OR, 1.555; 95% CI, 1.115-2.170; p=0.009) were more likely to identify ''lack of access to exercise opportunities'' as a barrier toward weight management. Those who met the physical activity guidelines (OR, 0.681; 95% CI, 0.510-0.911; p=0.010) were less likely to identify ''lack of access to exercise opportunities'' as a barrier toward weight management. While there were no significant main effects for age or smoking, an interaction effect between these two variables was found in the exploratory analysis (p=0.099). Firefighters who did not smoke cigarettes were 1.169 times more likely to identify ''lack of access to exercise opportunities'' as a barrier to weight management compared with firefighters who reported being current cigarette smokers. However, 60-year-old firefighters who did not smoke cigarettes were less likely (OR=0.303) to identify ‘‘lack of access to exercise opportunities’’ as a barrier for weight management than those currently smoking. Sex, body mass index, binge drinking, and fruit and vegetable consumption status were not associated with the firefighter’s identification of ‘‘lack of access to exercise opportunities’’ as a barrier to weight management (Table 10).

Eating helps me cope with stress so restricting foods could make my life more stressful

Age, sex, readiness for change, and body mass index status significantly contributed to the likelihood that firefighters identified eating as a way to cope with stress as a barrier to weight management. Older firefighters (OR, 0.989; 95% CI, 0.976-1.001; p=0.079) were less likely to identify ‘‘eating helps me cope with stress so restricting foods could make my life more stressful’’ as a barrier to weight management compared with younger firefighters. However, obese firefighters (OR, 1.351; 95% CI, 1.057- 1.727; p=0.016) and female firefighters (OR, 2.129; 95% CI, 1.401-3.234; p< 0.001), as well as those who were ready to begin a weight management program (OR, 1.850; 95% CI, 1.404-2.437; p< 0.001) were more likely to identify ‘‘eating helps me cope with stress so restricting foods could make my life more stressful’’ as a barrier to weight management. Physical activity, smoking, binge drinking, and fruit and vegetable consumption status were not associated with the firefighter’s selection of ‘‘eating helps me cope with stress so restricting foods could make my life more stressful’’ as a barrier toward weight management (Table 11).

Barriers burden—Summary index variable

Age, readiness for change, binge drinking, and fruit and vegetable consumption status contributed to the likelihood that firefighters had one or more barriers to weight management. Older (OR, 0.989; 95% CI, 0.979-0.999; p=0.025) firefighters and those who reported no binge drinking in the past month (OR, 0.768; 95% CI, 0.643-0.917; p=0.004) as well as those who met the fruit and vegetable consumption guideline (OR, 0.818; 95% CI, 0.675-0.991; p=0.040) were more likely to have zero barriers toward weight management. Firefighters who were ready to begin a weight management program (OR, 6.511; 95% CI, 1.820-23.294; p=0.004) were 6.5 times more likely to have one or more barriers to weight management compared with those who were currently working toward a healthier weight. An interaction (p=0.049) between age and readiness for change showed that showed that 30-year-old firefighters who were ‘‘ready to begin a weight management program’’ were 2.898 times more likely to have one or more barriers toward weight management than firefighters who were ‘‘currently working toward a healthy weight.’’ While the odds ratio for ‘‘ready to begin a weight management program’’ compared with ‘‘currently working toward a healthy weight’’ was in the same direction, it was not as strong for 60-year-old firefighters (OR=1.289). Sex, body mass index, physical activity, and smoking status were not associated with the firefighter’s identification of one or more barriers toward weight management (Table 12).

Discussion

This study examined barriers toward weight management among overweight or obese firefighters and explored potential correlates of these barriers among demographic characteristics, readiness for change status, and health risk factors. Prevalence estimates for barriers to weight management showed ‘‘lack of knowledge’’ was the most frequently identified barrier for male firefighters and ‘‘eating helps me cope with stress’’ for females. While more research is needed to better understand firefighters’ barriers to healthy behaviors, the results of this study are generally consistent with studies examining barriers to weight management and loss among adults. In reviews of the literature and the few published articles targeting behavioral weight management, barriers to weight management report ‘‘eating or overeating’’ or the ‘‘use of food’’ as a method to cope with stress among women and lack of knowledge and skills about weight management and healthy eating among men [114-120].

Among the exploratory models, readiness for change was the most important predictor of reporting specific barriers to weight management. Overweight firefighters who were ready to begin a weight management program were more likely to identify ‘‘lack of knowledge about weight management,’’ ‘‘lack of access to exercise opportunities,’’ ‘‘eating helps me cope with stress,’’ and report ‘‘one or more barriers toward weight management’’ compared with those who were currently working toward a healthier weight. However, readiness for change was part of a significant two-way interaction term with age for ‘‘lack of knowledge about weight management,’’ and ‘‘barriers burden.’’ Both interactions showed that 30- and 60-year-old firefighters who were ‘‘ready to begin a weight management program’’ were more likely to select ‘‘lack of knowledge’’ as a barrier and indicate have more than one barrier to weight management; however, the effect decreased with age. Firefighter age was also an important predictor in these exploratory models. When age was examined as an independent variable, younger firefighters were more likely to identify ‘‘lack of access to healthy foods'' and ''eating helps me cope with stress so restricting foods could make my life more stressful'' as barriers to weight management. Younger firefighters were also more likely to report having one or more barriers to weight management. An interaction of age and smoking status showed that younger (age 30), non-smoking firefighters were more likely to report ''lack of access to exercise opportunities'' as a barrier to weight management, while 60-year-old firefighters who were nonsmokers were less likely to identify ''lack of access to exercise opportunities'' as a barrier. Although challenging to interpret, these interactions expand the meaning of the relationships among the variables in the models and allow for more targeted program planning, setting the stage for future research. While body mass index, physical activity, smoking, binge drinking, and fruits and vegetables consumption status were significant factors in only one or two of the models, the relationship of these health risk factors with specific barriers to weight management seemed reasonable. Obese firefighters were more likely to identify ''eating helps me cope with stress'' compared with firefighters who were overweight but not obese. Firefighters who did not meet physical activity standards reported ''lack of access to exercise opportunities'' as a barrier. Those who did not meet the fruit and vegetable consumption guidelines reported ''lack of access to low calorie or healthy food'' as a barrier.

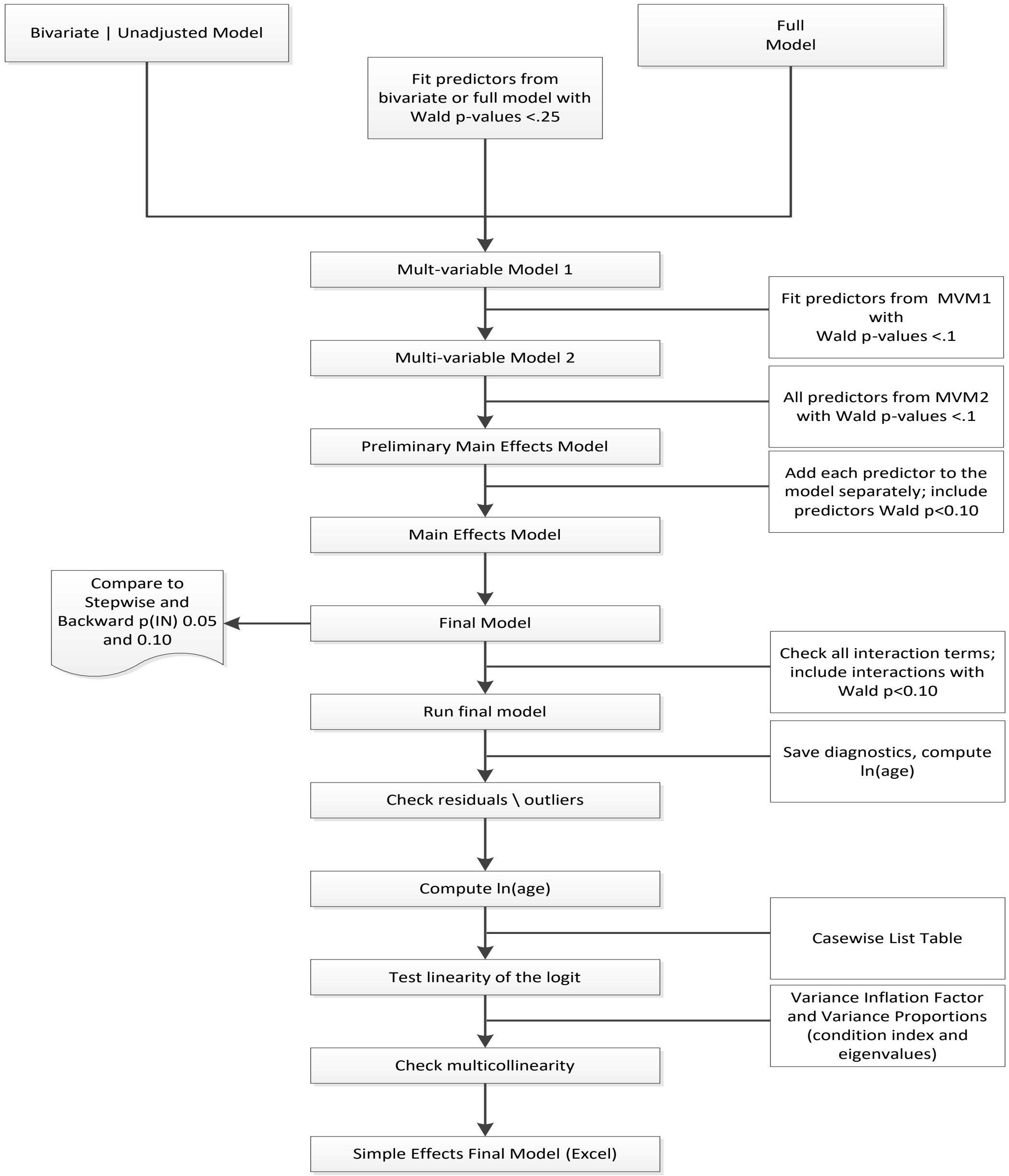
As far as we know, this is the first quantitative study exploring barriers to weight management among firefighters. While more research is needed to better understand the obstacles firefighters face to manage their weight, these results provide evidence that there is variation in factors influencing the barriers that firefighters identify for weight management. Thus, when translating the findings to intervention planning, it may be useful to focus programs on the predictors for the specific barriers. For example, knowledge- based programs would be targeted to male firefighters and those who were ready to start a program, whereas interventions focusing on eating as a coping mechanism for stress may be more effective among younger, obese, or female firefighters as well as those who were ready to begin a program.

Although strengths of this exploratory study include a large sample size and the ability to control for several factors simultaneously, there were also study limitations. The data used in the analysis were abstracted from health risk appraisal questionnaires collected during an occupational physical examination. Self-reported data such as height and weight as well as health-related behaviors are known to be less valid and reliable than clinical measures and may be subject to intentional or unintentional errors [121]. Another limitation is that individuals' perception of their weight status, a potentially important predictor, was not included in the HRA. In a 2011 study conducted by Poston et al [55], one-third (32.4%) reported themselves correctly as overweight; only 8.0% of the firefighters identified themselves correctly as obese. Furthermore, the likelihood of underestimating weight category increased by 24.0% (OR, 1.24; 95% CI, 1.18-1.31) for each increase in BMI measurement when controlling for age and other risk factors. Lastly, this was an exploratory study based on a convenience sample of urban Midwest firefighters where the results may not represent firefighters in other settings.

Future studies to examine findings similar to this exploratory analysis should be based on more robust study designs and take into account the relationship among the variables, particularly age and readiness for change.

In summary, readiness for change and age were important predictors in explaining firefighters' identification of barriers toward weight management. Understanding how firefighter characteristics influence barriers to weight management may be helpful in planning health promotion programming and interventions to more effectively help firefighters manage their weight. Efforts to reduce chronic disease morbidity and mortality through the mitigation of risk factors, such as overweight and obesity, would benefit firefighters, their families, the fire service, and the public. Perhaps now, more than ever, mitigating risk factors and subsequent chronic disease is multifaceted, including consideration of lifestyle, family history and genetics, social influences and occupational risks, particularly among firefighters. Health outcomes researchers and planners need to first understand these relationships in the populations under study, to better target the behavior change strategies to match the documented needs.

Figure 7. Model Selection Process



This figure shows the model selection process used to identify potential predictors for firefighter identification of barriers to weight management and the index variable, barriers burden.

Table 6. Attitudes, Risk Factors and Barriers to Weight Management by Sex (n=2,373)

	# (%)/Mean			Fishers exact probability test		
Characteristics	Male	Female	Total	Stat	df	p
Age						
19-39	685 (30.6%)	44 (33.1%)	729 (30.7%)	5.256	2	0.072
40-49	863 (38.5%)	60 (45.1%)	923 (38.9%)			
50+	692 (30.9%)	29 (21.8%)	721 (30.4%)			
Total	2240 (100%)	133 (100%)	2373 (100%)			
Mean Age	44.39	43.19	44.33			0.113
Body Mass Index						
Overweight	900 (40.2%)	75 (56.4%)	975 (41.1%)	12.971		<0.001
Obese	1340 (59.8%)	58 (43.6%)	1398 (58.9%)			
Total	2240 (100%)	133 (10%)	2373 (100%)			
Mean Body Mass Index	31.83	30.68	31.77			0.006
Attitudes toward Weight Management						
Ready to begin a weight management program	367 (16.4%)	28 (21.1%)	395 (16.65%)	1.65	1	0.186
Currently working toward a healthier weight	1873 (83.6%)	105 (78.9%)	1978 (83.4%)			
Total	2240 (100%)	133 (100%)	2373 (100%)			
Risk Factors						
Meets Physical Activity Guidelines (150 minutes: moderate + vigorous)	1568 (72.4%)	81 (65.3%)	1649 (72%)	2.54	1	0.1
Consumes five fruits and/ or vegetables per day	564 (25.2%)	56 (42.1%)	620 (26.2%)	17.62	1	<0.001
Not a current cigarette smoker	2109 (94.8%)	119 (89.5%)	2228 (94.5%)	5.961	1	0.016
No binge drinking in the past 30 days)	1320 (59.2%)	98 (74.2%)	1418 (60.1%)	11.11	1	<0.001
Barriers						
Lack of knowledge about weight management	425 (19%)	15 (11.3%)	440 (18.5%)	4.426	1	0.028
Lack of access to low-calorie or healthy foods	401 (17.9%)	18 (13.5%)	419 (17.7%)	1.361	1	0.241
Family or social group won't like or support a change	156 (7%)	14 (10.5%)	170 (7.2%)	1.889	1	0.12
Lack of access to exercise opportunities	253 (11.3%)	17 (12.8%)	270 (11.4%)	0.148	1	0.575
Eating helps me cope with stress so restricting foods could make my life more stressful	305 (13.6%)	33 (24.8%)	338 (14.2%)	11.98	1	<0.001
Barriers Burden						
Zero (0) Barriers	828 (37%)	46 (34.6%)	874 (36.8%)	0.211	1	0.644
One (1) or More Barriers	1412 (63%)	87 (65.4%)	1499 (63.2%)			

Table 7. Unadjusted and Final Binary Logistic Regression Model Estimates for Weight Management Barrier: Lack of Knowledge about Weight Management (lack of knowledge)

	Unadjusted Models					Final Adjusted Model				
				CI					CI	
Predictor	B	p-value	OR	Lower	Upper	b	p-value	OR	Lower	Upper
Age	-0.005	0.407	0.995	0.984	1.006	0.003	0.601	1.003	0.991	1.017
Female	-0.611	0.029	0.543	0.314	0.939	-0.687	0.015	0.503	0.289	0.877
Ready to begin a weight management program	0.768	<0.001	2.156	1.685	2.76	2.166	<0.001	8.719	2.605	29.185
Obese	-0.037	0.73	0.964	0.781	1.189	–	–	–	–	–
Meets physical activity guidelines	-0.197	0.092	0.821	0.653	1.033	–	–	–	–	–
Non-smoker (cigarettes)	-0.395	0.061	0.673	0.445	1.019	-0.377	0.079	0.686	0.45	1.045
No binge drinking in the past month	-0.112	0.297	0.894	0.724	1.103	–	–	–	–	–
Meets standard for fruit and vegetable consumption	-0.287	0.023	0.75	0.586	0.961	–	–	–	–	–
Age * Ready to begin a weight management program interaction	–	–	–	–	–	-0.031	0.023	†	†	†
Constant	–	–	–	–	–	-1.406	–	–	–	–

CI, confidence interval; OR, odds ratio.
† see text for interpretation of OR for 2 age groups
*p<0.001

Table 8. Unadjusted and Final Binary Logistic Regression Model Estimates for Weight Management Barrier: Lack of Access to Low-Calorie or Healthy Foods

	Unadjusted Models					Final Adjusted Model				
				CI					CI	
Predictor	B	p-value	OR	Lower	Upper	b	p-value	OR	Lower	Upper
Age	-0.026	<0.001	0.975	0.964	0.986	-0.025	<0.001	0.975	0.964	0.987
Female	-0.332	0.201	0.718	0.432	1.193	-0.267	0.308	0.765	0.458	1.280
Ready to begin a weight management program	-0.284	0.066	0.753	0.556	1.019	–	–	–	–	–
Obese	0.022	0.986	1.002	0.808	1.242	–	–	–	–	–
Meets physical activity guidelines	0.251	0.047	1.285	1.004	1.645	–	–	–	–	–
Non-smoker (cigarettes)	0.044	0.855	1.045	0.652	1.674	–	–	–	–	–
No binge drinking in the past month	-0.316	0.004	0.729	0.589	0.902	-0.223	0.044	0.800	0.644	0.995
Meets standard for fruit and vegetable consumption	-0.328	0.011	0.720	0.558	0.929	-0.336	0.011	0.715	0.553	0.925
Constant	–	–	–	–	–	-.0231	–	–	–	–

CI, confidence interval; OR, odds ratio.
*p<0.001

Table 9. Unadjusted and Final Binary Logistic Regression Model Estimates for Weight Management Barrier: Family or Social Group Won't Like or Support a Change

	Unadjusted Models					Final Adjusted Model				
				CI					CI	
Predictor	B	p-value	OR	Lower	Upper	b	p-value	OR	Lower	Upper
Age	-0.003	0.690	0.997	0.980	1.014	-0.003	0.724	0.997	0.98	1.014
Female	0.452	0.125	1.572	0.882	2.799	0.449	0.128	1.566	0.879	2.79
Ready to begin a weight management program	-0.014	0.949	0.986	0.648	1.502	–	–	–	–	–
Obese	0.128	0.433	1.137	0.825	1.567	–	–	–	–	–
Meets physical activity guidelines	0.175	0.352	1.192	0.823	1.725	–	–	–	–	–
Non-smoker (cigarettes)	0.171	0.648	1.186	0.570	2.469	–	–	–	–	–
No binge drinking in the past month	-0.081	0.614	0.922	0.672	1.265	–	–	–	–	–
Meets standard for fruit and vegetable consumption	0.080	0.652	1.084	0.764	1.537	–	–	–	–	–
Constant	–	–	–	–	–	-2.457	–	–	–	–

CI, confidence interval; OR, odds ratio.

Table 10. Unadjusted and Final Binary Logistic Regression Model Estimates for Weight Management Barrier: Lack of Access to Exercise Opportunities

	Unadjusted Models					Final Adjusted Model				
				CI					CI	
Predictor	B	p-value	OR	Lower	Upper	b	p-value	OR	Lower	Upper
Age	-0.003	0.621	0.997	0.983	1.010	0.035	0.186	1.035	0.983	1.090
Female	0.141	0.600	1.151	0.680	1.947	0.038	0.894	1.039	0.592	1.822
Ready to begin a weight management program	0.556	<0.001	1.745	1.290	2.358	0.442	0.009	1.555	1.115	2.170
Obese	0.051	0.700	1.052	0.813	1.363	–	–	–	–	–
Meets physical activity guidelines	-0.480	<0.001	0.619	0.471	0.812	-0.384	0.010	0.681	0.510	0.911
Non-smoker (cigarettes)	-0.624	0.008	0.536	0.337	0.851	1.506	0.244	4.507	0.357	56.871
No binge drinking in the past month	-0.138	0.292	0.871	0.673	1.126	–	–	–	–	–
Meets standard for fruit and vegetable consumption	-0.126	0.403	0.882	0.656	1.184	–	–	–	–	–
Age*Non-smoker (cigarette)	–	–	–	–	–	-0.045	0.099	†	†	†
Constant	–	–	–	–	–	-2.989	–	–	–	–

CI, confidence interval; OR, odds ratio.
† see text for interpretation of OR for 2 age groups
*p<0.001

Table 11. Unadjusted and Final Binary Logistic Regression Model Estimates for Weight Management Barrier: Eating Helps Me Cope with Stress so Restricting Foods Could Make my Life More Stressful

	Unadjusted Models					Final Adjusted Model				
				CI					CI	
Predictor	B	p-value	OR	Lower	Upper	b	p-value	OR	Lower	Upper
Age	-0.012	0.070	0.989	0.976	1.001	-0.011	0.079	0.989	0.976	1.001
Female	0.739	<0.001	2.094	1.387	3.160	0.755	<0.001	2.129	1.401	3.234
Ready to begin a weight management program	0.664	<0.001	1.944	1.480	2.552	0.615	<0.001	1.850	1.404	2.437
Obese	0.320	0.009	1.377	1.082	1.752	0.301	0.016	1.351	1.057	1.727
Meets physical activity guidelines	-0.310	0.016	0.733	0.570	0.944	–	–	–	–	–
Non-smoker (cigarettes)	0.026	0.920	1.027	0.615	1.713	–	–	–	–	–
No binge drinking in the past month	-0.020	0.866	0.980	0.775	1.240	–	–	–	–	–
Meets standard for fruit and vegetable consumption	0.114	0.385	1.121	0.867	1.449	–	–	–	–	–
Constant	–	–	–	–	–	-1.661	–	–	–	–

CI, confidence interval; OR, odds ratio.
*p<0.001

Table 12. Unadjusted and Final Binary Logistic Regression Model Estimates for Weight Management Barrier: Index Barriers Variable, Barriers Burden

	Unadjusted Models					Final Adjusted Model				
				CI					CI	
Predictor	B	p-value	OR	Lower	Upper	b	p-value	OR	Lower	Upper
Age	-0.016	<0.001	0.984	0.975	0.993	-0.011	0.025	0.989	0.979	0.999
Female	0.104	0.581	1.109	0.768	1.602	0.153	0.426	1.166	0.799	1.701
Ready to begin a weight management program	0.671	<0.001	1.957	1.531	2.501	1.874	0.004	6.511	1.820	23.294
Obese	0.104	0.229	1.109	0.937	1.314	–	–	–	–	–
Meets physical activity guidelines	-0.230	0.019	0.795	0.656	0.963	–	–	–	–	–
Non-smoker (cigarettes)	-0.311	0.114	0.733	0.498	1.077	–	–	–	–	–
No binge drinking in the past month	-0.317	<0.001	0.728	0.612	0.866	-0.264	0.004	0.768	0.643	0.917
Meets standard for fruit and vegetable consumption	-0.243	0.011	0.784	0.650	0.946	-0.201	0.040	0.818	0.675	0.991
Age* Ready to begin a weight management program	–	–	–	–	–	-0.027	0.049	†	†	†
Constant	–	–	–	–	–	1.170	–	–	–	–

CI, confidence interval; OR, odds ratio.
† see text for interpretation of OR for 2 age groups
*p<0.001

CHAPTER 5 DISCUSSION TO HEALTH IN INDIANA FIREFIGHTERS

This research found that Indiana firefighters are at risk for cancer and cardiovascular disease and other chronic conditions. The odds of death due to all malignant cancers were significantly higher among firefighters compared to a matched population of non-firefighters. Firefighters were also found to die of cancer of the buccal cavity and pharynx, pancreas, kidney, brain, and other parts of the nervous system. While CVD mortality, specifically ischemic heart disease, among firefighters was not in excess to that of the general population, heart disease was found to be the second leading cause of death (29.2%), just slightly lower than cancer at 30.4%, among firefighters for the years 1985 to 2013. The healthy worker effect (HWE) has been suggested to moderate excess mortality for cardiovascular deaths among firefighters when the general population is used as a reference [73]. The relationship may be further impacted by health promotion programs and services available to improve firefighter health. In Indiana, firefighters working in the largest fire department in the state have had access to annual physical examinations, clinical, fitness testing and evaluations, and other wellness services for more than 20 years. Firefighters working in other fire departments included in the *Excess Mortality among Indiana Firefighters, 1985-2013* analysis have had access to varying levels of clinical, fitness and health promotion programs throughout the same time period. The cardiovascular morbidity and mortality among firefighters may actually have been higher than that of the general population without these programs.

An examination of health status among firefighters in the beginning of their careers shows that most of the measures were in optimal or near optimal status at baseline, the first job-related physical examination. However, an examination of data over time showed a significant trajectory toward increased risk as early as five years into the career and continued to worsen by the tenth year of the firefighters' career. These results support earlier studies showing that firefighters experiencing sudden cardiac deaths and CVD retirements had statistically higher levels of CVD risk factors [35, 40, 41] and other studies of firefighters at all ages showed elevated prevalence of CVD risk factors among this occupational group [35, 50, 90-94].

To manage these risks, firefighters need to be able to identify and overcome barriers to the implementation of programs and adoption of healthy behavior. Prevalence estimates for barriers to weight management showed "lack of knowledge" was the most frequently identified barrier for male firefighters and "eating helps me cope with stress" for female firefighters. In addition, age, stage of readiness to change, and health behaviors were related to specific reported barriers to weight management. While more research is needed to better understand the obstacles firefighters face to manage their health, these results provide evidence that there is variation in factors related to the barriers firefighters identify for weight management. Understanding these underlying factors may help in the development of more effective interventions to support better weight management.

The strengths of this research include (1) use of longitudinal valid and reliable clinical measures, (2) the use of robust epidemiological and statistical analysis techniques to examine data enhancing investigators' ability to control for potential confounding and include firefighters with partially missing data, (3) large sample sizes providing adequate power to assess relationships between predictors and outcomes and (4) the use of novel data sets to build an understanding of firefighter health and risk factors.

The limitations of this research include (1) the use of convenience samples limiting generalizability, (2) a lack of occupational and lifestyle-related exposure information, (3) limited information on exposures related to firefighters' second jobs, (4) potential for misclassification of cause of death, risk factor status and disease categories, (5) limited knowledge of cultural factors affecting health, (6) limited numbers of females and minority race firefighters preventing robust sub-group analysis, and (7) the use of self-reported information which are known to be less reliable [121].

In summary, these projects support the importance of early-career and targeted cardiometabolic health and cancer prevention strategies to reduce chronic disease and morbidity and mortality among firefighters. These findings support the conceptual model put forth (Figure 1) targeting gaps in knowledge concerning leading causes of death, risk factors among new firefighters and an exploration to understand the health behaviors of Indiana firefighters. The model highlights a complex inter-relationship among exposures, barriers, and behaviors influencing health outcomes and risk factors that are not well-understood for firefighters.

Recommendations

The results from this research suggest a need to develop and implement effective strategies for early surveillance, intervention, and education programs targeted on firefighters' cardiometabolic and cancer and other chronic disease prevention. Firefighters would benefit from health intervention programs as early as recruit school and lasting throughout their careers as firefighters. Next steps at the federal level include working to identify firefighters as a vulnerable population, as well as providing firefighter access to health screening and diagnostic evaluations on a schedule commensurate with the risk of the job or providing resources to obtain those screenings through certified occupational medical practices. Federal resources need to continue to be allocated to the development of both federal- and state-level health and disease registries to track and monitor health and health risk factors among firefighters to enhance health care and prevention programs. Firefighters would benefit from fire departments and municipalities allocating resources toward annual physical examinations, health monitoring, and fitness evaluation following the current firefighter recommendations for cancer, cardiovascular, and infectious disease screening. Lastly, but most importantly, it is important that firefighters take personal responsibility for their own health. It is not good enough for the firefighter to “pass” a physical examination or fitness test to get or keep a firefighting job. Firefighters need to understand the value of maintaining their health throughout their careers. Firefighters, the number one resource of the United States Fire Service, owe it to themselves, their families and communities they serve to take personal responsibility for their health. Much like personal protective equipment, which is not effective unless used properly, firefighters will not be able to maintain their health over their career without attention to good nutrition, physical activity, smoking cessation, injury prevention, appropriate clinical screenings, and behavioral health management through health care and prevention programs offered to them.

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116. Johnson, PH. and J.J. Annesi, *Factors Related to Weight Gain/Loss among Emerging Adults with Obesity.* Am J Health Behav, 2018. **42**(3): p 3-16.
117. Garip, G. and L. Yardley, *A synthesis of qualitative research on overweight and obese people's views and experiences of weight management.* Clin Obes, 2011. **1**(2-3): p 110-26.
118. Munt, A.E., S.R. Partridge, and M. Allman-Farinelli, *The barriers and enablers of healthy eating among young adults: a missing piece of the obesity puzzle: A scoping review.* Obes Rev, 2017. **18**(1): p 1-17.
119. Ashton, L.M., et al., *Motivators and Barriers to Engaging in Healthy Eating and Physical Activity.* Am J Mens Health, 2017. **11**(2): p 330-343.
120. Teixeira, PJ., et al., *Successful behavior change in obesity interventions in adults: a systematic review of self-regulation mediators.* BMC Med, 2015. **13**: p 84.
121. Connor Gorber, S., et al., *A comparison of direct vs. self-report measures for assessing height, weight and body mass index: a systematic review.* Obes Rev, 2007. **8**(4): p 307-26.

CURRICULUM VITAE

Carolyn Marie Muegge

Education

December 2020	Indiana University	PhD	Epidemiology
August 2001	Indiana University	MPH	Epidemiology
December 1991	Purdue University	MS	Health and Kinesiology
August 1998	Purdue University	BA	Community Health

Professional Experience

July 2013-Current	Research Scientist, Investigator, Ascension Public Safety Medicine National Institute for Public Safety Health Indianapolis, IN
October 2011-August 2013	Network Director of Research Development Community Network Indianapolis, IN
December 2000-October 2011	Research Manager, Project Director (Intern to Manager); Indiana University Department of Family Medicine Bowen Research Center, Indianapolis, IN

Honors, Awards, Fellowships Research and Training Experience

2020	IUPUI Elite 50, Graduate and Professional Student Excellence Award, 2020
2016	Winner, Student and New Researchers Poster Competition, November 2016, American Public Health Association Annual Meeting Occupational Health Section.
2011	Member, Delta Omega, Honorary Society in Public Health May 2011
2001	Member of team awarded the Partnership for Healthy Children Award for the Tobacco Free Marion County Project, November 2001 American Public Health Association, 129th Annual Meeting and Exposition
1999	Member of the team recognized by the American College of Occupational and Environmental Health, recipient of the Corporate Achievement Award City of Indianapolis and Marion County Sheriff's 5 Department Health Management Program

RESEARCH ACTIVITY

Manuscripts

Muegge CM, Zollinger TW, Song Y, Wessel J, Monahan PO, **Moffatt SM**. Barriers to Weight Management among Overweight and Obese Firefighters. JOEM. 2020; 62(1):37-45. doi: 10.1097/JOM.0000000000001751

Muegge CM, Kleinschmidt VM, Johnson KA, Sotos-Prieto M, Moffatt SM, Beverly EA, Korre M, Kales SN. Focus groups to inform a nutrition intervention for career firefights. Clin Nutr Metab. 2019; 1(2):1-5 doi 10.15761/CNM.1000108.

Muegge CM, Zollinger TW, Song Y, Wessel J, Monahan PO, **Moffatt SM**. Excess Mortality Among Indiana Firefighters, 1985-2013. American Journal of Industrial Medicine. 2018; 61(12):961-967. doi:10.1002/ajim.22918.

Sotos-Prieto M, Cash SB, Christophi C, Folta S, Moffatt S, **Muegge CM**, Korre M, Mozaffarian D, Kales SN. Rationale and Design of Feeding Amierica's Bravest: Mediterranean Diet-Based Intervention to change Firefighters' Eating Habits and Improve Cardiovascular Risk Profiles. Contemp Clin Trials. 2017, doi: 10.1016/j.cct.2017.07.010.

Saywell RM, Zollinger TW, Moffatt, Galloway C, **Muegge CM**, Kochhar K. A Cohort Mortality Study of Indianapolis Firefighters 1970-2006: What Are Our Firefighters Dying From? Fire Chief. February 2011.

Chamness BE, Zollinger TW, **Muegge CM**, West JM, Thompson WR, Ainsworth BE. Building a City-Level Fitness Index: American College of Sports Medicine's American Fitness Index™ International Making Cities Livable Documentation Set #55, 2009.

Mendenhall D, Moffatt S, Williams T, Reeves J, Greeson J, Shelton CS, Stahl H, Zollinger TW, Saywell RM, **Muegge CM**. Validation of a Physical Work Performance Evaluation for Incumbent Firefighters. Fire Engineering, December 2005.

Zollinger TW, Saywell RM, **Muegge CM**, Bogda LJ, Cummings SF, Wooldridge JA. The Impact of Household Smoking on Child Tobacco Use, Attitudes and Knowledge. International Journal of Health Promotion and Education. 2005; 43(2):45-50.

Zollinger TW, Saywell RM, **Muegge CM**, Wooldridge JS, Cummings SF, Caine VA. Impact of the Lifeskills Training Curriculum on Middle School Students Tobacco Use in Marion County, Indiana. Journal of School Health. 2003; 73(9):338-46.

Saywell RM, Champion VL, Zollinger TW, Maraj M, Skinner CS, Zoppi KA, **Muegge CM**. The Cost Effectiveness of Five Interventions to Increase Mammography Adherence in a Managed Care Population. The American Journal of Managed Care. 2003; 9:33-44.

Muegge CM, Zollinger TW, Saywell RM, Moffatt SM, Hanify T, Dezelan LA. Indianapolis Fire Department's Experience with CPAT: Putting the Test to the Test. Fire Engineering. 2002;155(8):97-102.

Technical Reports

Lewis CL, Hashu JA, Brandt AJ, Richard AE, Sheff Z, **Muegge CM**, Zollinger TW. AFI Technical Assistance Program, Oklahoma City Needs Assessment: Results of Key Informant Interviews. For the American College of Sports Medicine, December 2011.

Chamness BE, **Muegge CM**, Lewis CK, West JM, Zollinger TW, Thompson WR, Ainsworth BE. ACSM American Fitness Index™, Actively Moving U.S. Cities to Better Health, 2011 Report. For the American College of Sports Medicine, June 2011.

McGill M, **Muegge CM**, Mosier L, Brooks M, Hillman K, Reynolds V, Parrish T. Brandt A. Impact of the Indiana Women's Diabetes Initiative, Final Report, With the Indiana State Department of Health, Office of Womens Health, February 2011.

Muegge CM, Coffing J, Brandt A, Canada M, Zollinger TW. Good Samaritan Hospital Knox County Needs Assessment Survey Report. For Good Samaritan Hospital, January 2011.

Muegge CM, Coffing JM, Canada ML, Brandt AJ, Zollinger TW. American College of Sports Medicine's American Fitness Index™ Awareness and Use Report. For the American College of Sports Medicine, December 2010.

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Zollinger TW, Saywell RM, **Muegge CM**. OnBase Medical Record System User Satisfaction Survey. For Wishard Health Care System, October 2009.

Muegge, CM, West JM, Zollinger TW. American College of Sports Medicine's American Fitness Index™ Awareness and Use Report. For the American College of Sports Medicine, July 2009.

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Chamness BE, Zollinger TW, **Muegge CM**, Thompson WR, Ainsworth BE, West JM, Beacom BC. ACSM American Fitness Index™, Actively Moving U.S. Cities to Better Health 2008 Edition. For the American College of Sports Medicine, February 2009.

Muegge CM, Zollinger, West JM, Robinson JJ. Exercise Is Medicine. For the American College of Sports Medicine, July 2009.

Chamness BE, Zollinger TW**, Muegge CM**, Thompson WR, Ainsworth BE, West JM, Beacom BC. ACSM American Fitness Index™, Actively Moving U.S. Cities to Better Health 2008 Edition. For the American College of Sports Medicine, February 2009.

Zollinger TW, **Muegge CM**, Sutton B. Assessment of Indiana Health Professions Recruitment and Retention Program. For the Indiana State Office of Rural Health, November 2008.

Zollinger TW, Saywell RM, **Muegge CM**, Przybylski MJ. The Economic Impact of Secondhand Smoke on Indiana in 2007. For Smoke Free Indiana and the Indiana tobacco Prevention and Cessation Agency, June 2008.

Chamness BE, Zollinger TW, **Muegge CM**, Thompson WR, Ainsworth B with West JM, Beacom BC. ACSM American Fitness Index™, Actively Moving U.S. Cities to Better Health Pilot Phase. For the American College of Sports Medicine, May 2008.

Muegge CM, Zollinger TW, Saywell RM. An Evaluation of Smokefree Indiana's Comprehensive Tobacco Control Program for FY 2007, For Smokefree Indiana, December 2007.

Jewell N, Ellison C, Roberson C, Ohmit A, Lincoln F, De Jesus R, Saywell K, Zollinger TW, Przybylski M, **Muegge CM**, Kochhar K, Galloway C. Indiana Minority Health Surveillance System Project. For the Indiana Minority Health Coalition Racial and Ethnic Minority Epidemiology Center, November 2007.

McKeag DB, Zollinger TW, Allen DI, Przybylski MJ, Holloway AM, Kochhar K, **Muegge CM**, Emery EJ Issue Brief: Indiana's Health Professions Workforce Shortage and Mal-distribution. For the Indiana Health Care Reform Study Group, October 2007.

McKeag DB, Zollinger TW, Allen DI, Holloway AM, **Muegge CM**, Przybylski MJ, Kochhar K, Brokaw JJ, Wilson JS, Wright ER. Report of the Workforce and Workforce Development Subcommittee of the Indiana University Health Reform Study Group For the Indiana Health Care Reform Study Group, October 2007.

Zollinger TW, **Muegge CM**, Emery EJ, Galloway CM. Analysis of Programs to Recruit and Retain Primary Care Physicians in Rural Areas of Indiana. For the Indiana State Office of Rural Health, July 2007.

Muegge CM, Zollinger TW, Saywell RM. An Evaluation Plan for Smoke Free Indiana's Comprehensive Tobacco Control Program for FY 2008, For Smoke Free Indiana, June 2007.

Muegge CM, Zollinger TW, Saywell RM. An Evaluation of Smoke Free Indiana's Comprehensive Tobacco Control Program for FY 2006, For Smoke Free Indiana, March 2007.

Zollinger TW, **Muegge CM**, Njinimbam FN, Kim D, Galloway C. The Impact of a Publicly Accessible Trail: The Eel River Bluff Trail Study, For Logansport Memorial Hospital, March 2007.

Gibson PJ, Zollinger TW, Moriarty SR, Lahsaee H, Saywell RM, **Muegge CM**, Caine VA. 2005 Marion County Adult Obesity Needs Assessment Telephone Survey Report. Marion County Health Department and Health and Hospital Corporation of Marion County, November 2005.

Zollinger TW, Saywell RM, **Muegge CM**. Underutilization Study for the Indiana Poison Control Center. For Poison Control Center, December 2003.

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Muegge CM, Zollinger TW, Saywell RM, Moffatt SM, Hanify T, Dezelan LA, Schroeder B.CPAT: Applicant Attrition, Pre-Test Training and Pass Rates, For Indianapolis Fire Department, August 2002.

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Zollinger TW, **Muegge CM**, Wooldridge JS. Tobacco Free Youth Initiative Marion County Health Department, Evaluation Report. For Marion County Health Department, September 2001

Zollinger TW, Saywell RM, **Muegge CM**. ADVANTAGE Health Plan After Hours Telephone Response Study. For Sagamore Health Network, October 2000.

Zollinger TW, Saywell RM, **Muegge CM**. ADVANTAGE Health Plan Provider Satisfaction Survey. For Sagamore Health Network, October 2000.

Zollinger TW, Saywell RM, **Muegge CM**. ADVANTAGE Health Plan Behavioral Health Access Study. For Advantage Health Plan, October 2000.

Zollinger TW, Saywell RM, **Muegge CM**. Healthy Expectations Program Deaconess Family Practice Center, Year Two Evaluation. For Deaconess Family Practice Center, June 2000.

Presentations and Posters

Muegge CM, Zollinger TW, Song Y, Wessel J, Monahan PO, Moffatt SM. Excess Mortality among Indiana Firefighters, 1985-2013. American Heart Association Epi | Lifestyle Scientific Sessions, Workplace Health, New Orleans LA, 2018. (poster).

Muegge CM, Zollinger TW. Excess Mortality among Indiana Firefighters for 1985-2013. American Public Health Association Annual Meeting and Expo, Occupational Health and Safety, Denver, CO, 2016. (poster).

Muegge CM, Zollinger TW, Moffatt SM. Perceived Barriers to a Healthy Lifestyle in Firefighters. American Public Health Association Annual Meeting and Expo, Occupational Health and Safety, Denver, CO, 2016. (presentation).

Muegge CM, Stone C, Cooper W, Crowe-Storm L. Northwest Area Community Assessment: A Qualitative Evaluation of Resident's Perceptions about the Neighborhood. IUPUI Center for Service & Learning, Bingle Civic Engagement Showcase and Symposium, Poster Presentation, May 2014. (poster).

Muegge CM, Stone C, Cooper W, Crowe-Storm L. Northwest Area Community Assessment: A Qualitative Evaluation of Resident's Perceptions about the Neighborhood. Indiana Joint National Public Health Week Conference, Poster Presentation, Indianapolis, IN, April 2014. (poster).

Burch S, Richter Lisa, **Muegge CM**. Quality of Medical Treatment Regimens in Wikipedia. American College of Osteopathic Family Physicians 2013 Convention, Poster Presentation, Original Research, Las Vega, NV, March 2013. (poster).

Burtea ED, **Muegge CM**, Hern T, Leins M, Lozier T, Curry S, Lisby M, Franklin M, Mastin M, McNew CS, Zoppi K. The C4 Project: Transforming the Family Medicine Residency into a Patient-Centered Medical Home. 45th Annual Workshop for Directors of Family Medicine Residencies (PDW), Kansas City, MO, April 2013. (poster)

Muegge CM, Burtea ED, Hern T, Leins M, Lozier T, Curry S, Lisby M, Franklin M, Mastin M, McNew CS, Zoppi K. The C4 Project: Transforming the Family Medicine Residency into a Patient-Centered Medical Home. Association for Hospital Medical Education, Fort Lauderdale, FL, May 2012. (poster)

Muegge CM, Burtea ED, Hern T, Leins M, Lozier T, Curry S, Franklin M, Mastin M, McNew CS, Zoppi K. Novel Residency Education in the Patient-Centered Medical Home. Association for Hospital Medical Education, Fort Lauderdale, FL, May 2012. (poster)

Lewis CK, Zollinger TW, **Muegge CM**, Thompson W, Ainsworth B, Chamness B. A Community-level Fitness and Health Index: American College of Sports Medicine's American Fitness Index. North American Primary Care Research Group Annual Meeting, Banff, Canada, November 2011. (presentation)

Muegge CM. Presenting Program Findings: Making Data Talk. Indiana Public Health Training Center, Leading, Connecting, and Succeeding in Public Health, Summer Conference Meeting. Indianapolis, IN, August 2011.

Muegge CM, Mosier L, Brooks M, Hillman K, Reynolds V, Parrish T. Kunapareddy S. Impact of the Indiana Women's Diabetes Initiative. Centers for Disease and Prevention 2010 Diabetes Translation Conference. Kansas City, MO. April 2010. (poster)

Muegge CM, Mosier L, Brooks M, Hillman K, Reynolds V, Parrish T. Kunapareddy S. Impact of the Indiana Women's Diabetes Initiative. Kokomo Medical Society, Kokomo, IN. March 2010.

Muegge CM, Mosier L, Brooks M, Hillman K, Reynolds V, Parrish T. Kunapareddy S. Impact of the Indiana Women's Diabetes Initiative. Centers for Disease and Prevention 2010 Diabetes Translation Conference. Kansas City, MO. April 2010. (poster)

Muegge CM, Mosier L, Brooks M, Hillman K, Reynolds V, Parrish T. Kunapareddy S. Impact of the Indiana Women's Diabetes Initiative. American Public Health Association 137th Annual Meeting and Exposition. Philadelphia, PA. November 2009. (poster)

Allen DA, **Muegge CM**, Robinson JJ. Assessment of the Indiana Family Physician Workforce by Practice Location. North American Primary Care Research Group Annual Meeting, Montreal, Quebec, Canada, November 2009.

Allen DA, **Muegge CM**, Mckeag D, Robinson JJ. Trends in the Indiana Family Physician Workforce: Preliminary Findings. Fifth Annual AAMC Physician Workforce Research Conference. Boston, MA. 2009. (poster)

Zollinger TW, Chamness BE, **Muegge CM**, West JM, Thompson WR, Ainsworth BE. Building a City-Level Fitness Index: American College of Sports Medicine's American Fitness Index. American College of Sports Medicine Annual Meeting, May 2009.

Chamness BE, Zollinger TW, **Muegge CM**, West JM, Thompson WR, Ainsworth BE. Building a City-Level Fitness Index: American College of Sports Medicine's American Fitness Index. 47th International Making Cities Livable Conference, Portland, OR, May 2009.

Mosier L, **Muegge CM**, Brooks M, Hillman K, Kerner J. Reynolds V, Parrish T. Indiana Women's Diabetes Initiative. Indiana Joint National Public Health Week Conference. Indianapolis, IN, May 2009. (poster)

Newbauer A, **Muegge CM**, Mosier L, Brooks M, Hillman K, Kerner J. Reynolds V, Parrish T. Indiana Women's Diabetes Initiative. Life Health Science Presentations. Indianapolis, IN, April 2008. (poster)

Kochhar K, Zollinger TW, Saywell RM, Moffatt SM, Galloway C, **Muegge CM**. "Cohort Mortality Study of Indianapolis Firefighters 1970-2006. What are our firefighters dying from?" North America Primary Care Research Group Annual Meeting, Rio Grande, Puerto Rico, November 15-19, 2008. (poster)

Allen DA, **Muegge CM**, Mckeag D, Robinson JJ. Trends in the Indiana Family Physician Workforce: Preliminary Findings. North American Primary Care Research Group Annual Meeting. Rio Grande, Puerto Rico. November 2008. (poster)

Chamness BE, Zollinger TW, **Muegge CM**, West JM, Thompson WR, Ainsworth BE. Building a City-Level Fitness Index: American College of Sports Medicine's American Fitness Index. 25th International Council for Physical Activity and Fitness Research Symposium, Loma Linda, CA, September 2008.

Sutton BS, Custer JL, **Muegge CM**, Zollinger TW, Barclay JC, Brokaw JJ, Wilson JS, Deal DW, White GW, Holloway AM, Kiovsky RD. ImPACT Indiana: Improving the Populations' Access to Care and Training. National Area Health Education Center Organization Conference. Denver, CO. June 2008.

Zollinger TW, Saywell RM, **Muegge CM**, Przybylski MJ, Spitzangle MH. Comparison of Attitudes about Exposure to Second Hand Smoke Among Rural, Semirural, Suburban and Urban Residents in Indiana. Indiana Rural Health Association 11th Annual Conference, French Lick, IN, June 2008. (poster).

Chehresa A, **Muegge CM**, Countryman N, Kochhar K, Brokaw JJ, Allen DI, Nalin PM, Holloway AM, Zollinger TW. The Impact of the Primary Care Workforce Distribution on Health Outcomes. Indiana Rural Health Association 11th Annual Conference, French Lick, IN, June 2008. (poster)

Chehresa A, **Muegge CM**, Countryman N, Kochhar K, Brokaw JJ, Allen DI, Nalin PM, Holloway AM, Zollinger TW. The Impact of the Primary Care Workforce Distribution on Health Outcomes. Fourth Annual AAMC Physician Workforce Research Conference, Washington DC, April-May 2008. (poster)

Chehresa A, **Muegge CM**, Countryman N, Kochhar K, Brokaw JJ, Allen DI, Nalin P, Holloway AM, Zollinger TW. The impact of the Primary Care Workforce Distribution on Health Outcomes. Indiana Academy of Family Physicians Research Day, Indianapolis, IN, March 2008.

Allen DI, and **Muegge CM**. INET Update. IAFP State Meeting, IAFP, Fort Wayne, IN, July, 2006.

Allen DI, O'Neil J, **Muegge CM**. Increasing Parental Management of Teen Drivers Through Primary Care Offices: Using Both Family Physicians and Pediatricians in an Interventional Study. School of Medicine, Dean's Grand Rounds, Indianapolis, IN, September 2006. (poster)

Allen DI, and **Muegge CM**. INET Update. Indiana Family Medicine Residents' Day and Research Forum, IAFP, Indianapolis, IN, March, 2006.

Gupta MP, Zollinger TW, **Muegge CM**, Gibson PJ, Saywell RM. Impact of Demographic Characteristics on Access to Physical Activity Opportunities. American Public Health Association Annual Meeting and Exposition, Philadelphia, PA, December 2005.

Gupta MP, Zollinger TW, **Muegge CM**, Gibson PJ, Saywell RM. Impact of Demographic Characteristics on Access to Physical Activity Opportunities. INShape Indiana Conference, Indianapolis, IN, November 2005.

O'Neil J, Allen DI, **Muegge CM**. Intervention to Increase Parental Management of Teen Driving Behavior. Indiana Multidisciplinary Child Care Conference. Indianapolis, IN, May 2005

Allen DI, O'Neil J, **Muegge CM**. Intervention to Increase Parental Management of Teen Driving Behavior. North American Primary Care Research Group Quebec City, Canada, October 2005

Allen DI, and **Muegge CM**. INET Update. IAFP State Meeting, IAFP, French Lick, IN, July, 2005.

Allen DI, O'Neil J, **Muegge CM**. Using Both Family Physicians and Pediatricians in an Interventional Study. AAFP National Research Network Convocation of Practices, Colorado Springs, CO, March 2005.

Moffatt S, Mendenhall D, Williams T, Shelton CS, Zollinger TW, Sawyell RM, **Muegge CM**. Validation of a Physical work Performance Evaluation for Incumbent Firefighters. Steps to a Healthier U.S. Workforce NIOSH Conference, Washington, DC, October 2004.

Zollinger TW, Saywell RM, Jr., **Muegge CM**, Wooldridge JS, Factors that Explain a Child's Decision to Smoke. School of Medicine, Dean's Grand Rounds, Indianapols, IN, September 2004.

Zollinger TW, Saywell RM, Jr., **Muegge CM**, Wooldridge JS. Factors that Explain a Child's Decision to Smoke. Society for Research and Tobacco, New Orleans. LA, February 2003. (poster)

Zollinger TW, Saywell, Jr., RM, **Muegge CM**, Wooldridge JS, Bogda L, Cummings SF. Impact of Smokers in the Household on Children's Behavior, Attitudes and Beliefs. National Conference on Smoking or Health, San Francisco, CA, November 2002.

Muegge CM, Zollinger TW, Saywell, Jr., RM, Moffatt SM, HanifyT, Dezelan LA. CPAT: Putting the Test to the Test. School of Medicine, Dean's Grand Rounds, Indianapolis, IN, September 2002. (poster)

Zollinger TW, Saywell, Jr., RM, **Muegge CM**, Wooldridge JS, Bogda L, Cummings SF. Impact of Smokers in the Household on Children's Behavior, Attitudes and Beliefs. School of Medicine, Dean's Grand Rounds, Indianapolis, IN, September 2002. (poster) Multi-component Program on Students' Tobacco Use, Knowledge, Attitudes and Behaviors. American Public Health Association, Atlanta, GA, October 2001

Silvey (Muegge) CM, Lyle R. Effect of Menstrual Cycle Phase on Cardiovascular Reactivity in Oral Contraceptive Users with a Parental History of Hypertension. Research presented at the American Alliance for Health and Physical Education & Recreation (AAHPRD) poster session. San Francisco, CA, April 1991. (poster)

Muegge CM, Mosier L, Brooks M, Hillman K, Kunapareddy S. Indiana Women's Diabetes Initiative. HHS Directors and Evaluators Meeting, Washington DC, June 2010.

Muegge, CM, Chamness BE, Zollinger TW, Thompson WR, Ainsworth BE, West JM. ACSM American Fitness Index™: Translating Data Into Action. American College of Sports Medicine Annual Meeting, Baltimore, MD, June 2010.

Muegge CM, Mosier L, Brooks M, Hillman K, Reynolds V, Parrish T. Kunapareddy S. Impact of the Indiana Women's Diabetes Initiative. Centers for Disease and Prevention 2010 Diabetes Translation Conference. Long Beach, CA April 2010.

Muegge CM, Mosier L, Brooks M, Hillman K, Reynolds V, Parrish T. Kunapareddy S. Impact of the Indiana Women's Diabetes Initiative. Indiana Joint National Public Health Week Conference. Indianapolis, IN April 2010.

Muegge CM. Presenting Program Findings: Telling Your Story. Indiana Primary Healthcare Association Annual Meeting. Indianapolis, IN, October 2009.

Muegge CM, Mosier L, Brooks M, Hillman K, Kerner J. Reynolds V, Parrish T. Indiana Women's Diabetes Initiative. HHS Directors and Evaluators Meeting, Washington DC, June 2009.

Muegge CM, Mosier L, Brooks M, Hillman K, Kerner J. Reynolds V, Parrish T. Description of a Pilot Diabetes Navigation Program Using Community Lay Workers. CDC Diabetes Translation Conference 2009. Long Beach, CA, April 2009.

Muegge CM , Chehresa A, , Countryman N, Kochhar K, Brokaw JJ, Allen DI, Nalin PM, Holloway AM, Zollinger TW. The Impact of the Primary Care Workforce Distribution on Health Outcomes. APHA 136th Annual Meeting and Exposition, San Diego, CA, October 2008.

Moffatt S, Mendenhall D, Williams T, Shelton CS, Zollinger TW, Saywell RM, **Muegge CM**. "Validation of a Physical Work Performance Evaluation for Incumbent Firefighters." Steps to a Healthier U.S. Workforce NIOSH Conference, Washington, D.C. October 2004.

FUNDING

2020 Surveillance of Coronavirus Infection among Indiana Firefighters, PENDING, Federal Emergency Management Association, Co-Investigator ($1,500,000).

2019 Cancer Among Indiana Firefighters: Case Control Studies, funded by Federal Emergency Management Association, Co-Investigator ($1,500,000)

2011 American Fitness Index, Phase II, Principal Investigator, funded by the American College of Sports Medicine ($57,000)

2011 Data Analysis and Evaluation Assistance for the 2011 ACSM American Fitness Index Program, Principal Investigator, funded by the American College of Sports Medicine ($20,000)

2011 2010-2011 Annual Indiana Flex Program Evaluation, Principal Investigator, funded by the Indiana State Department of Health, Office on Rural Health ($30,000)

2011 Community Health Network, Indianapolis, IN, The C4 Project: Transforming Family Medicine Residency Training and Practice into a Patient-Centered Medical Home, funded by Community Health Network

2010 Good Samaritan Hospital Community Health Survey, Principal Investigator, funded by the Good Samaritan Hospital ($27,761)

2009-2010 Data Analysis and Evaluation Assistance for the 2010 ACSM American Fitness Index (AFI) Program and Survey Development for the Exercise Is Medicine Program, Principal Investigator, funded by the American College of Sports Medicine ($46,062)

2008-2009 Assistance in Developing the American Fitness Index (AFI), Principal Investigator, funded by the American College of Sports Medicine ($84,053)

2007-2008	Assistance in Developing the American Fitness Index, Principal Investigator, funded by the American College of Sports Medicine ($41,149)
2009-2010	ASIST 2010 Supplement 3, Principal Investigator, funded by Indiana State Department of Health ($17,500)
2009-2010	Advancing Systems Improvements to Support Targets for Healthy People 2010: ASIST 2010 Year 2, Principal Investigator, funded by Indiana State Department of Health ($36,914)
2009-2010	Advancing Systems Improvements to Support Targets for Healthy People 2010: ASIST 2010 Year 2, Principal Investigator, funded by Indiana State Department of Health (Supplement $6,217)
2009-2010	Advancing Systems Improvements to Support Targets for Healthy People 2010: ASIST 2010 Year 2, Principal Investigator, funded by Indiana State Department of Health (Supplement $20,695)
2008-2009	Advancing Systems Improvements to Support Targets for Healthy People 2010: ASIST 2010 Supplement 1, Principal Investigator, funded by Indiana State Department of Health ($10,000)
2008-2009	Response of Physicians to Patients Inquiries: INET Principal Investigator, funded by Purdue University ($1,896)
2007-2008	Racial Differences in Physician-Patient Communication for Cancer Pain Management: INET Principal Investigator, funded by Purdue University ($5,237)
2007-2008	Advancing Systems Improvements to Support Targets for Healthy People 2010: ASIST 2010 Year 2, Principal Investigator, funded by Indiana State Department of Health ($48,450)
2007- 2008	Advancing Systems Improvements to Support Targets for Healthy People 2010: ASIST 2010 Year 1, Principal Investigator, funded by Indiana State Department of Health, ($30,000)